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Final report

SIDE INTERIOR STIFFNESS MEASUREMENT

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16. Abstract

A study was done to catalog the stiffness characteristics of door areas, A-pillars, B-pillars, and roof rails of several vehicles. Dynamic component tests were performed on the door interiors and various upper interior structures using rigid thoracic and head impactors. Static crush tests were done on the door exteriors. Results of these tests are presented.

Injury potentials were estimated by repeating these tests using a SID thorax impactor and a Part 572 head impactor. These potentials were then correlated to the measured stiffness characteristics. The results of these correlations are presented and discussed.

Head to A-pillar impacts were also performed on the HYGE sled using Citation and Rabbit sled bucks and a full Part 572 dummy. In addition, thoracic component tests were done as part of a preliminary study to examine the effect of lowering the hood profile of the striking vehicle. Results and observations from these tests are presented.

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TECHNICAL SUMMARY

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A study was done to catalog the stiffness characteristics of door areas, A-pillars, B-pillars, and roof rails of several vehicles. Using the component test device at the VRTC, the door areas were tested in two ways. Dynamic impacts were performed on the door interiors using a rigid surrogate chest and static crush tests were done on the door exteriors. Using the same component test device, but with a rigid surrogate head, dynamic impacts were performed on the various upper interior structures. These rigid impactor tests measured the stiffness characteristics of the structures.

The significance of the stiffness characteristics variations was also examined. For this study, a SID thorax impactor and a Part 572 headform impactor were used to perform tests identical to those utilizing the rigid impactors. From these tests, injury potentials were estimated, and by applying linear regression techniques, they were correlated to the measured stiffness characteristics.

A total of nine full dummy head to A-pillar impacts were done on the HYGE sled using a Citation and a Rabbit as sled fixtures. The purpose of these was to estimate how closely the sub-system test resembled "real world" types of occurrences.

Finally, a preliminary study was done to examine the effect of lowering the hood profile of the striking vehicle. This was done by progressively lowering the honeycomb that interfaces the static crush device and the exterior door. Interior impacts using the SID thorax were then performed to measure response. This investigation was intended as a lead-in to a series of crash tests that will explore striking vehicle aggressiveness attributes.

(Continue on additional pages)

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1.0 INTRODUCTON

In side impacts, injury to occupants is caused by the contact of the occupant with one or more of the various interior surfaces, or structures, of the vehicle. For instance, a majority of thoracic injuries are due to an impact with the interior area of the door. Likewise, a large number of head injuries result from the head striking upper interior structures such as the A-pillar.

It may be possible that a change in the stiffness characteristics of these interior structures could reduce their injury causing potential. Since the door area and upper structures are prominent injury causing interior surfaces for the thorax and head, respectively, the stiffness characteristics of these structures were measured for several vehicles.

This report states the approach and hardware used in this study and presents the results of the stiffness measurements. In addition, it reviews the effort made to determine the significance of the stiffness variations through an attempt to relate injury to the measured stiffness characteristics.

2.0 OBJECTIVES

The objectives of this project were to catalog the stiffness characteristics of door areas, A-pillars, B-pillars, and roof rails of several vehicles, and to determine the significance of the measured variations. In addition, tests were performed to measure the effect of striking vehicle hood height, using the VRTC thoracic component test device.

3.0 PROJECT ELEMENT SUMMARY

The Safety Research Laboratory approach consisted of four project elements. The following is a brief description of these elements.

Project Elements	Summary Description
1	Catalog the exterior and interior door area stiffness characteristics of several vehicles.
2	Catalog the interior stiffness characteristics of the A-pillar, B-pillar, and roof rail regions from several vehicles.
3	Determine the significance of measured stiffness variations on the head and thorax.
4	Make a preliminary investigation of the effect of striking vehicle hood height.

4.0 PROJECT ELEMENT OVERVIEW

The following is a description of each project element.

PROJECT ELEMENT ONE: Catalog the exterior and interior door area stiffness characteristics of several vehicles.

This project element included performing dynamic impact tests on the interior doors of seven vehicles. A rigid thorax was used to measure the stiffness characteristics of the door systems.

Two crash environments were simulated, an occupant compartment collision and a non-compartment strike. For the first, the door was statically crushed prior to testing. For the latter, this was not done. These exterior crushes also resulted in force versus deflection data.

PROJECT ELEMENT TWO: Catalog the interior stiffness characteristics of the A-pillar, B-pillar, and roof rail regions from several vehicles.

This project element included performing dynamic head impact tests on three or four upper interior structures of each vehicle. The structures were the A-pillar, side roof rail, front roof rail, and the B-pillar (4-door vehicles only). A rigid headform was used to measure the stiffness characteristics of the structures.

PROJECT ELEMENT THREE: Determine the significance of head and thorax stiffness variations.

This project element consisted of three major tasks. The first was to determine a relationship between chest injury and the stiffness characteristics measured in the rigid thorax tests. This type of correlation was attempted separately on component test data from seven vehicles and on crash test data from four vehicles. These component tests utilized a SID thorax as the surrogate chest.

The second task was to find a relationship between the HIC found from component tests using a Part 572 headform and the stiffness characteristics measured in the rigid headform component tests.

The final task was to conduct full dummy and vehicle body HYGE sled tests and to determine a transfer function, if one exists, between these test results and those of the head component tests.

PROJECT ELEMENT FOUR: Make a preliminary investigation of the effect of striking vehcile hood height.

This project element consisted of two tasks. The first was to perform a series of SID thorax component tests which examined the effect that lowering the hood height of the striking vehicle has on rib response. Since the front end of the striking vehicle was simulated in the component test approach by a piece of aluminum honeycomb, this investigation could be done by simply incrementally lowering the vertical placement of this honeycomb on the door.

The second task was to conduct a preliminary survey of front end profiles that are currently being produced.

5.0 DOOR AREA TESTING

5.1 Approach

Two component tests were performed on each vehicle structure investigated. The first of these used a rigid impactor that measured stiffness properties of the structure. The other determined the significance of the stiffness variations by estimating the injury due to an impact with that structure. This last type of test used an impactor built from dummy parts, in an attempt to achieve a greater biofidelity than that exhibited by the rigid impactor.

The component test procedure developed measured a vehicle's interior door stiffness under two environments. The first of these was the case in which a vehicle was struck in the side, but not in the occupant compartment region. The second was the case of the direct occupant compartment impact.

In order to develop the test procedure for these two situations, it was first necessary to examine the crash environment in each of the two conditions. In a non-compartment strike, the occupant and interior door are thrust against each other. The door, at contact, is typically not deformed and there is no exterior structure crushed against it. A reasonable door interior stiffness measurement for this type of collision would be one in which a rigid thorax moves into the interior of an undeformed, unbacked-up door.

In a compartment strike, the crash environment becomes much more hostile. As the striking vehicle contacts the door, the door is crushed inward and impacts the occupant. Therefore, at the time of door-to-occupant contact, the door has been crushed until its interior surface reaches the occupant seated position. In addition, the exterior of the door is backed by the front end of the striking vehicle.

A reasonable stiffness measurement for this type of collision would therefore have two stages. The first stage would be an exterior crush of the door. The door would be statically crushed until the interior door surface reaches the occupant seated position. The second stage would be to propel the rigid thorax into the crushed door.

In the case of a compartment impact, it is important to realize that the stiffness of the surface contacted by the thorax is composed of two elements. The first is the crushed door itself. The second is the front end of the striking vehicle. To simulate the latter in these component tests, the pre-crush and impact were performed with a piece of aluminum honeycomb used as the interface between the crushing device and the exterior of the door. The honeycomb was that developed for use on the NHTSA moving deformable barrier.

Separate tests were performed to determine the significance of the variations in stiffness. These tests utilized the SID thorax as the impactor.

Before this testing could begin, it was necessary to define several test parameters. First of all, the speed at which to propel the thorax into the door was determined. From previous component tests, a speed of 20 mph was found to produce significant injury levels, but was not so severe as to cause excessive damage to the hardware. Therefore, the tests using the SID thorax were performed with an impact speed of 20 mph. The tests using the rigid impactor were conducted with a slightly higher impact speed to assure sufficient deflection of the impacted surface.

The interior impact location was another parameter that had to be defined. Conceptually, the site chosen was the door region that a fiftieth percentile occupant, normally seated (seat at the mid-adjustment point), would contact in an intersection collision in which both vehicles are moving. With an occupant normally seated, a line was drawn between the mid-point of the rib-cage and the door, 15 degrees forward of the perpendicular to the door. The point at which this line intersected the door was the impact point. Its selection assumed that in an intersection collision the door displaces rearward slightly as well as laterally, relative to the occupant.

Finally, the angle at which the thorax moved into the door, the impact angle, was chosen. An angle of 90 degrees was selected so that the bending effect of the impact device was minimized.

Once the parameters were defined, it was possible to set a standardized procedure. The first stage in performing an unbacked door (non-compartment strike) test was to position the vehicle so that the thorax struck the chosen impact location. The vehicle was then secured to the floor to prevent it from moving during the test. At this point, the thorax was shot into the door at the predetermined impact speed. These tests did not damage the side structure of the vehicle, with the exception of the door. Therefore a second test could be performed on each side by simply replacing the door.

When a crushed door (compartment strike) test was performed, the vehicle was again positioned and then secured to the floor. The door was then crushed until the interior panel has displaced to the occupant seated position. A standard interior panel displacement of six inches was set. As the door was crushed, force/deflection data of this exterior crush were recorded. Once the crushing was completed, the thorax was propelled into the door at the predetermined impact speed. Obviously, these tests destroyed the side integrity of the vehicle. Therefore, they were the second tests done on each side.

Appendix A contains a sample of photographs depicting various stages of the thoracic tests performed on the Rabbit.

5.2 Hardware

A component test device was constructed at the SRL for earlier component testing. Briefly, this device consisted of a large triangular frame that was adjustable about three axes. With this frame, the impactor could reach inside the vehicle being tested such that a number of interior structures could be impacted. A hydraulic ram accelerator was mounted on the end of this frame. This was used, along with its accompanying pump and controls, to propel the body part surrogate at the desired speed (see figure 5.1).

When conducting thoracic tests, the thoracic impactor was mounted on the

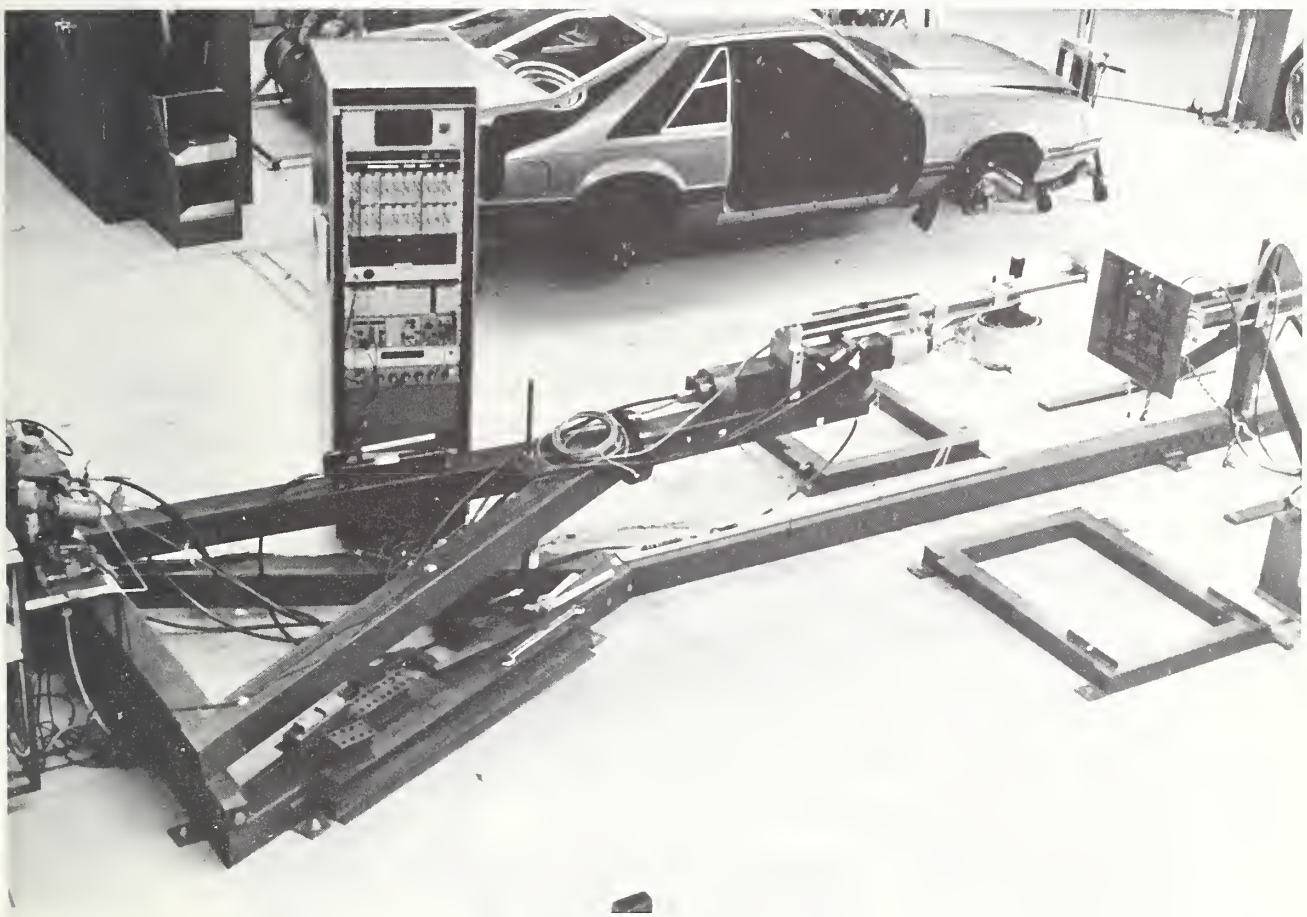


Figure 5.1 Component Test Device

accelerator. This device supported the surrogate chest and guided it laterally into the door being tested. When injury estimation tests were performed, the SID thorax was used as the thoracic impactor. Tests for measuring the stiffness of the doors were done with a rigid thorax in place (see figures 5.2 and 5.3, respectively). This rigid thorax was built such that the mass and impact surface area were similar to those of the SID thorax. The weight of the rigid thorax was 60.9 pounds.

Also shown in figure 5.1 is the pre-crush device. This apparatus was powered by a hydraulic pump and controlled by a servo-valve mechanism. An 18" x 18" x 5" piece of aluminum honeycomb (45 psi) was mounted on its large plate and used as the crushing interface, as a hydraulic actuator extended to crush the door. The rectangular frames on the floor were used to secure the vehicle during all stages of testing.

5.3 Test Matrix

Twelve vehicles were originally selected for use in this project. Appendix C contains a detailed discussion of the vehicle selection process as well as a final list of selected cars. The number of cars tested was later reduced to seven and they were as follows:

Honda Civic (2-door)
Plymouth Horizon (4-door)
Volkswagen Rabbit (2-door)
Pontiac Phoenix (4-door)
Ford Mustang (2-door)
Ford Granada (2-door)
Chevrolet Malibu (2-door)

Table 5.1 is the door area test matrix followed for five of the vehicles. Since the Granada and the Horizon had previously been crash tested and the left side damaged, only the crushed door tests were performed on them.

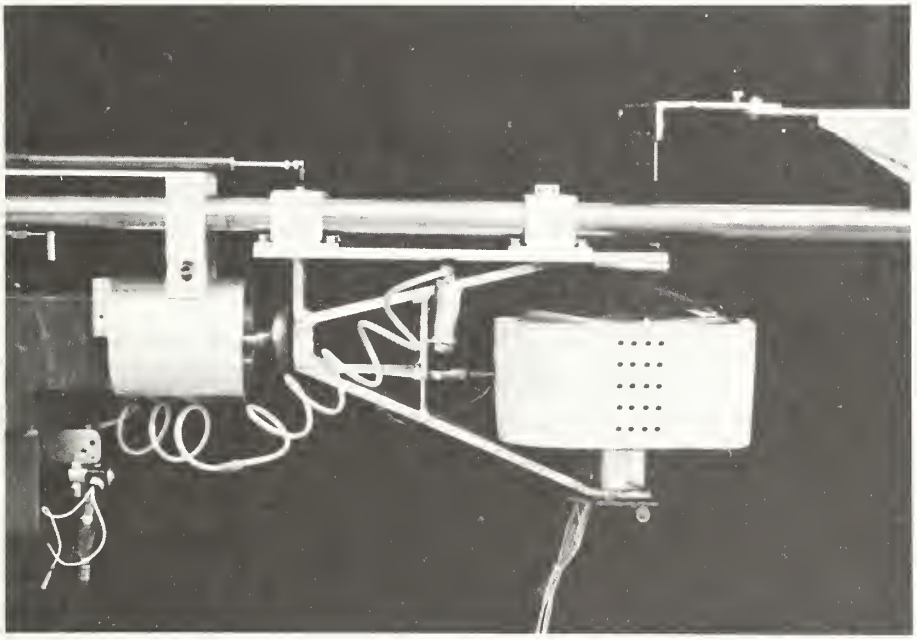


Figure 5.2 Thoracic Impactor - SID Thorax

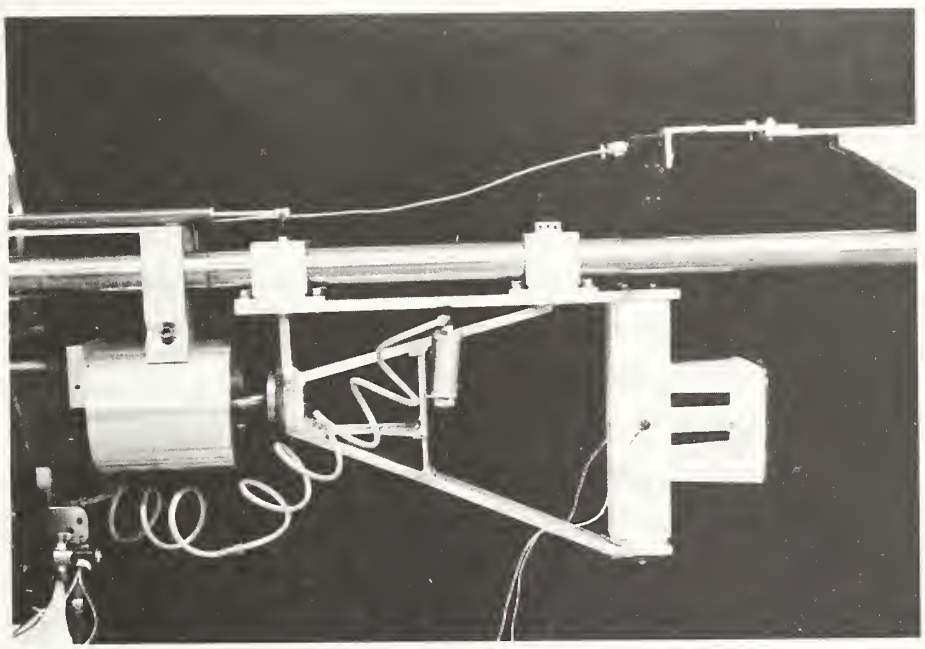


Figure 5.3 Thoracic Impactor - Rigid Thorax

Table 5.1

DOOR AREA TEST MATRIX

DOOR CONDITION	THORAX	
	RIGID	SID
UNBACKED DOOR		
CRUSHED DOOR		

6.0 UPPER INTERIOR TESTING

6.1 Approach

Many of the serious to fatal injuries that occur in side impact collisions are due to the head striking various interior structures of the vehicle. The most common of these structures include the side and front roof rails as well as the A and B pillars. For this reason, component tests were done which measured the interior stiffness properties of these structures. This was accomplished by propelling a rigid headform into the structure of interest.

As was the case with the thorax tests, it was also desirable to determine the significance of structural stiffness variations by conducting tests that allowed injury estimations to be made on these same structures. Therefore, component tests that used a headform built from a dummy head were also done.

The head of a Part 572 dummy was adapted for use on the head component test device. An attempt to maintain the headform biofidelity was made by including several factors in its design. First of all, the head was cut so that impact would occur on the forehead through the center of gravity of the headform. Next, a headskin from a Part 572 dummy head was adapted for use on the impactor. Finally, an investigation was

made to determine a representative mass for the headform. Appendix D contains a description of the steps taken to arrive at an effective mass of the head. A value of nine (9) pounds, not including the headskin, was chosen.

In a real accident that involves a head impact, the head of the occupant moves into the interior structure along a line from his/her original seated position. In addition, due to the relatively short distances between the head and the various interior structures, it is reasonable to assume that the head follows a nearly horizontal path. The angle of impact in the horizontal plane can vary, as it depends on the direction of force of the collision.

For the tests being done at the VRTC, it was necessary to compromise on the interior approach angles due to two constraints. The first was the size of the impactor. In some cases, it was not possible to achieve the "ideal" angle due to the length of the accelerator/impactor and the limited space in the vehicles. The other constraint was that the impactor had only one linear degree of freedom. As a consequence, it was necessary to chose an impact angle that was nearly perpendicular to the structure, in order to minimize the bending loads on the impactor.

The possible shortcomings of this head impactor for future uses were recognized. An impactor that will allow glancing impacts to be conducted is currently being developed in another SRL project (SRL-73, "Head Component Test/Accident Correlation"). In addition, HYGE sled tests were done that used a full dummy and vehicle body to realistically simulate head impacts in an accident.

As with the thorax component tests, it was necessary to set an impact speed at which to conduct the head tests. Earlier head component tests indicated that an impact speed of 15 mph produced significant injury levels, but was not so severe as to cause excessive damage to the hardware. The injury estimation tests were therefore conducted at an impact speed of 15 mph. The stiffness measurement tests used a slightly higher velocity.

The final parameter essential for conducting the head component tests was the impact location. First, a fiftieth percentile occupant was normally seated. Points were chosen on the front and side roof rails such that the occupant's head

struck perpendicular to the rails. Horizontal lines were drawn from the occupant's head to each of the two pillars. The points where the lines intersected these structures were chosen as impact locations on the A and B-pillars.

Since head tests using both the rigid headform and the Part 572 headform were performed, it was necessary to locate two impact points on each structure. These were found by simply straddling the points found above. A distance of about two inches in each direction was found to be needed so that the indentations resulting from the impacts did not overlap.

Once the parameters were defined, it was possible to set a standardized procedure for the head component tests. The vehicle and impactor were first positioned so that impact occured at the selected point. The angles were adjusted such that the direction of impact was through the occupant seated position and perpendicular to the structure being tested. If these two conditions were not compatible, preference was given to a perpendicular strike. The vehicle was then supported off of its suspension to minimize movement of the vehicle body. Finally, the headform was propelled into the structure at the predetermined velocity.

Appendix B contains a sample of photographs depicting various set-ups of head tests performed on the Rabbit.

6.2 Hardware

A head impactor was constructed to mount on the end of the hydraulic accelerator described in section 5.2 (see figure 6.1). The headform was mounted to an aluminum ram which slid through an aluminum guide sleeve along teflon bearings. This design allowed the headform to coast freely into, and rebound from, the structure being tested.

Tests conducted for injury estimation used the Part 572 headform described in section 6.1. This headform had a lead ballast so that the metal skull, the aluminum ram, the lead, and the connecting bolts totalled a mass of nine (9) pounds. The headskin added another 1.4 pounds to this total (see figure 6.1). The rigid headform used to measure stiffness properties also attached to the head impactor ram. It consisted of an aluminum hemi-sphere of 6.5" diameter and a lead ballast, such that its total mass of 9.1 pounds approximated that of the other headform (see figure 6.2).

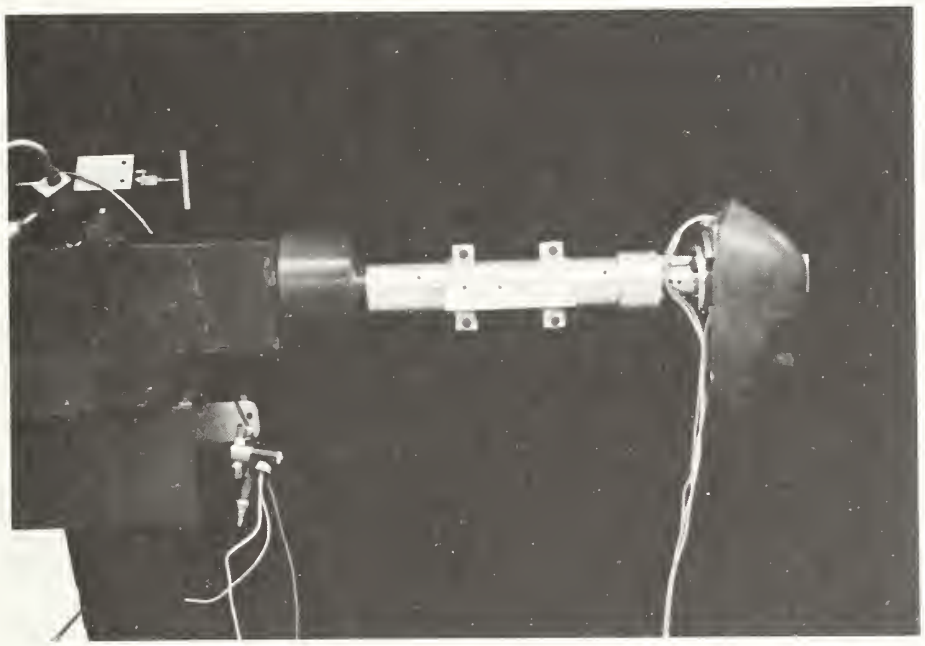


Figure 6.1 Part 572 Head Impactor

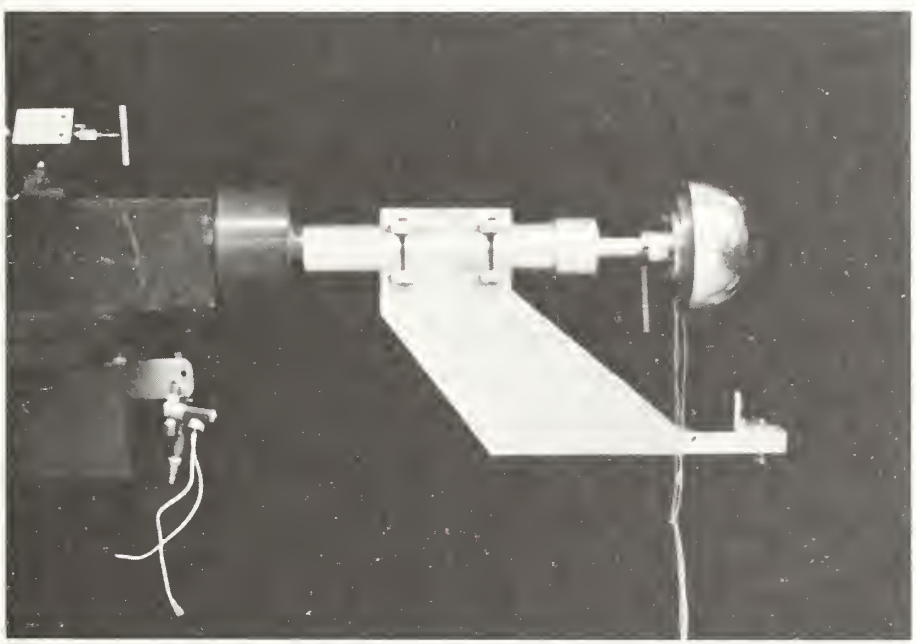


Figure 6.2 Rigid Head Impactor

6.3 Test Matrix

Five of the vehicles listed in section 5.3 were tested according to the upper interior test matrix shown in Table 6.1. Since the Granada and Horizon had previously been crash tested, the left side structures were damaged. Since the rigid headform tests had been given preference over the Part 572 headform tests, only the rigid headform tests were performed on these two vehicles.

Table 6.1
UPPER INTERIOR TEST MATRIX

HEADFORM	STRUCTURE			
	A-PILLAR	B-PILLAR*	SIDE ROOF	FRONT ROOF
RIGID				
PART 572 HEADFORM				

*B-pillar tests were done on 4-door cars only.

7.0 RESULTS OF DOOR AREA AND UPPER INTERIOR TESTING

7.1 Data Analysis Methods and Instrumentation

The data collected from tests with the rigid impactors were used to find the stiffness properties of the various structures. Data gathered from tests using the SID thorax and the Part 572 headform were used to determine the significance of stiffness variation by estimating injury.

The instrumentation on the SID thorax consisted of ten accelerometers (8 lateral, 2 off-axis), a linear chest displacement potentiometer, and a 20 inch solid rod linear potentiometer that measured the overall displacement of the spine. The rigid thoracic chestform had two lateral accelerometers as well as the 20 inch displacement potentiometer. Each of the two headforms contained three accelerometers mounted in a tri-axial configuration.

Acceleration data measured during rigid impactor tests were used to calculate impact force. These accelerations were first filtered using a low-pass, IIR, phaseless, Butterworth filter with cutoff and stopband frequencies of 300 Hz and 950 Hz, respectively. Impact force was then found by multiplying these accelerations by the rigid thorax and rigid headform masses of 61.80 and 9.12 lbs., respectively. Displacement for thoracic tests was measured directly from the 20" linear displacement potentiometer, while that for the headform tests was found by integrating the 1650 Hz acceleration data.

Since the magnitude of the displacements encountered during head testing were much smaller than those encountered during thoracic testing, slight movement of the vehicle as a rigid body could cause a significant error. Therefore, two methods were used to help reduce this error. First, the vehicle was supported off of its suspension. This helped to reduce the magnitude of the rigid body motion. Secondly, a 3" linear displacement potentiometer was used to measure this motion in the direction of impact. This measured displacement was then subtracted from the integrated displacement to give a better approximation of the true structural deflection.

Force vs. deflection curves were generated to document the energy absorption properties of the various structures. The data were then truncated to include data from the time of impact to the time of maximum force. Using a least-squares linear curve-fit, two straight lines were fitted through the data. One of these was simply the best fit line regardless of the intercept. The other was the best fit line given an intercept of zero pounds.

If stiffness is defined as the slope of the force vs. deflection curve, then the straight line fit which passes through zero gives the best stiffness for comparative purposes. The reason for this is that the fit line with the non-zero intercept could have a slope of nearly zero and a large intercept. If injury is to be correlated to stiffness, this would obviously not be a realistic indication of the stiffness which causes that injury. Therefore, the stiffness values listed in the legends of the graphical overlays are those of the fit lines with zero intercept. Since the non-zero intercept fit line information is useful for comparing rise times and curve shapes, it is included in tables.

Occupant responses from impacts with structures of these stiffnesses were estimated using the SID thorax and the Part 572 headform as impactors. The acceleration data measured by the SID thorax were processed using the standard thoracic filtering routine which employed the HSRI finite impulse response filter (1). Head injuries were estimated from 1650 Hz acceleration data. First, a resultant acceleration was calculated using data from the three tri-axially mounted accelerometers. The head injury criterion, HIC, was then found from this resultant.

7.2 Door Area Impacts

Table 7.1 gives the results of the door area tests performed on the seven vehicles. The stiffnesses listed here are those found from the slope of the best fit line with an intercept of zero. The rib and spine accelerations shown represent the average of the upper and lower regions. Also, the rigid thoracic impactor was used to measure the stiffness of the honeycomb interface and this result is listed. Table 7.2 lists the "true" slopes and intercepts of the best fit lines for these same tests.

Figure 7.1 shows plots of force vs. deflection of the unbacked door tests for the five cars tested in this mode. Figure 7.2 depicts plots of force vs. deflection of the crushed door tests for all seven vehicles. The stiffness, slope, and intercept values listed in tables 7.1 and 7.2 were calculated using the "rising" portion of these curves.

7.3 Upper Interior Impacts

Table 7.3 gives the results of the upper interior tests performed on the seven vehicles. As before, the stiffnesses listed here are those found from the best fit line with an intercept of zero. The slopes and intercepts listed are those found from the true best fit line. Note that the A-pillars were tested in more than one location. The purpose of this was to examine whether indentation of the A-pillar sheet metal is the sole factor in determining stiffness, or whether the bending of that structure is an additional factor. If the latter is true, then it is expected that the pillar stiffness will be less in the center than near the top. Finally, one repeat test was performed on each of the Rabbit and Phoenix. This was to help determine the integrity of the approach used in this study.

Table 7.1

DOOR STIFFNESS vs. RESPONSE

VEHICLE	DOOR CONDITION	STIFFNESS (lb/in)	PEAK ACCELERATIONS	
			RIBS	SPINE
RABBIT	UNBACKED	551	52.9	40.4
	CRUSHED	1789	89.8	89.9
CIVIC	UNBACKED	299	42.9	40.8
	CRUSHED	1488	102.4	87.7
PHOENIX	UNBACKED	522	78.7	37.9
	CRUSHED	1572	110.7	83.0
MUSTANG	UNBACKED	357	43.6	36.6
	CRUSHED	1891	81.1	84.3
MALIBU	UNBACKED	1070	92.7	43.6
	CRUSHED	1711	122.3	84.1
GRANADA	CRUSHED	1306	89.4	87.1
HORIZON	CRUSHED	668	57.6	56.6
HONEYCOMB ONLY		STIFFNESS = 2440 lb/in		

Table 7.2

DOOR - SLOPES and INTERCEPTS

VEHICLE		UNBACKED	CRUSHED
RABBIT	SLOPE INTERCEPT	464 lb/in 279 lb	2438 lb/in -1439 lb
CIVIC	SLOPE INTERCEPT	154 lb/in 614 lb	2006 lb/in -1114 lb
PHOENIX	SLOPE INTERCEPT	380 lb/in 257 lb	2341 lb/in -530 lb
MUSTANG	SLOPE INTERCEPT	456 lb/in 90 lb	2678 lb/in -1496 lb
MALIBU	SLOPE INTERCEPT	1001 lb/in 1027 lb	2243 lb/in -1018 lb
GRANADA	SLOPE INTERCEPT	xxxx xxxx	1648 lb/in -829 lb
HORIZON	SLOPE INTERCEPT	xxxx xxxx	711 lb/in -150 lb
HONEYCOMB	SLOPE INTERCEPT	2528 lb/in -124 lb	

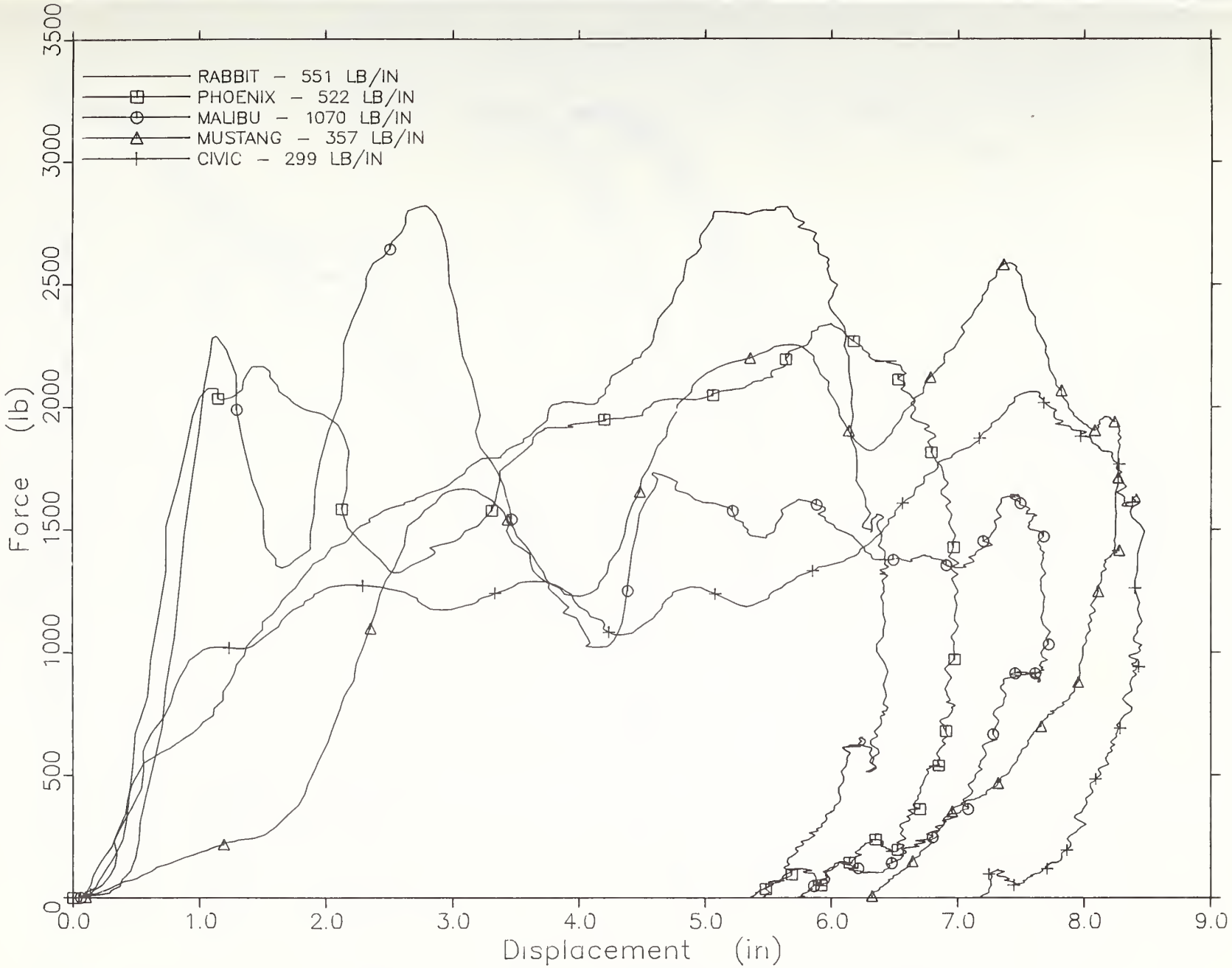


FIGURE 7.1. UNBACKED DOORS

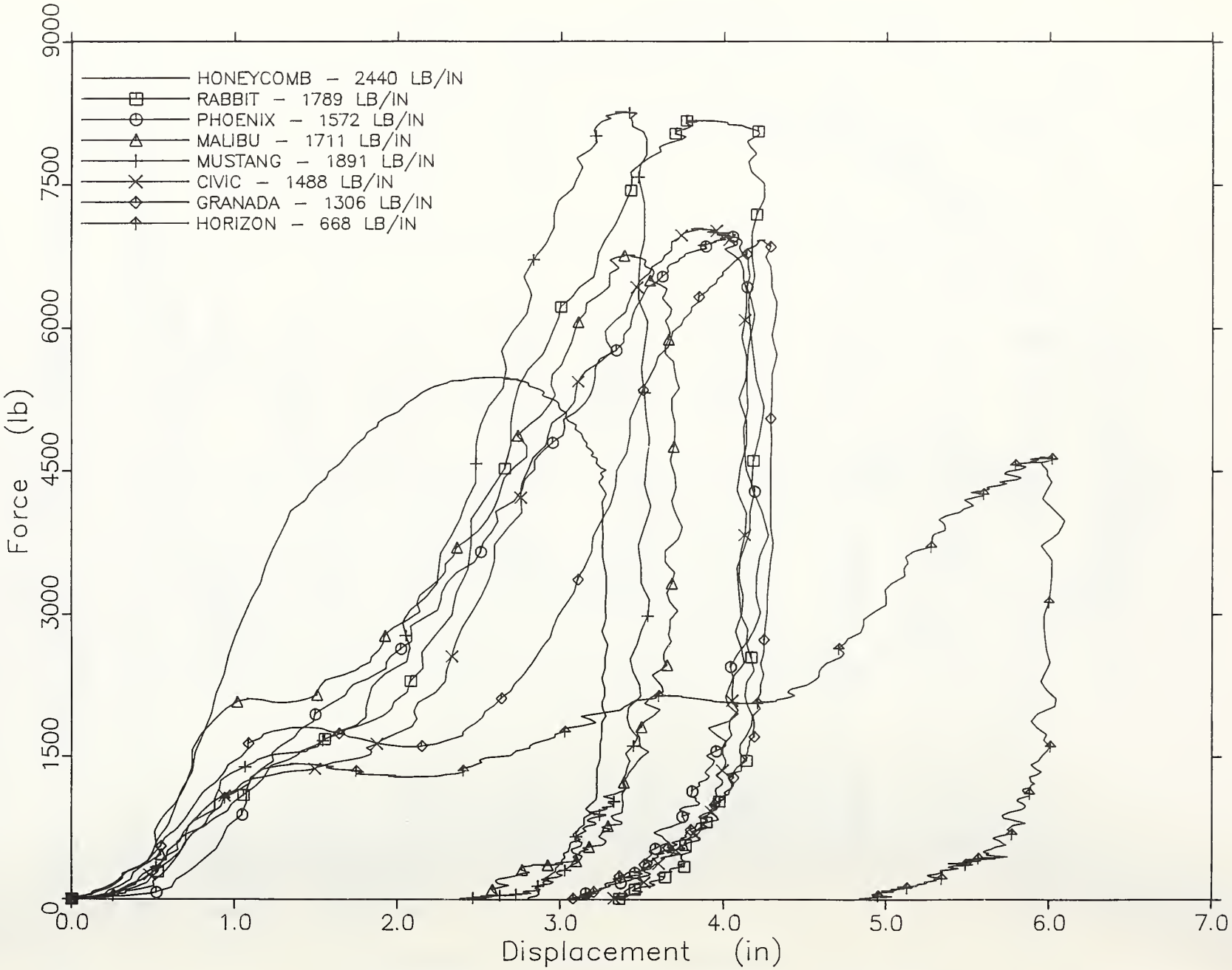


FIGURE 7.2. CRUSHED DOORS

Table 7.3
STRUCTURAL STIFFNESS vs. HIC

VEHICLE	STRUCTURE	STIFFNESS (lb/in)	HIC	SLOPE (lb/in)	INTERCEPT (lb)
RABBIT	SIDE ROOF RAIL	876	782	1414	-277
	A-PILLAR (upper)	1987	xxx	2787	-454
	A-PILLAR (lower)	1470	1698	2049	-374
	A-PILLAR (lower)	xxxx	1523	xxxx	xxx
	FRONT ROOF RAIL	356	358	603	-288
PHOENIX	B-PILLAR	1022	972	1530	-294
	SIDE ROOF RAIL	1607	1309	1966	-170
	A-PILLAR (upper)*	2387	2024	3557	-529
	A-PILLAR (middle)	1675	1669	2479	-484
	A-PILLAR (lower)	1658	xxxx	2513	-499
	A-PILLAR (middle)	1596	xxxx	2401	-405
	FRONT ROOF RAIL	1015	640	1379	-190

* The cross-section here was an overlap joint (i.e. double thickness sheet metal).

Table 7.3 Cont.
STRUCTURAL STIFFNESS vs. HIC

VEHICLE	STRUCTURE	STIFFNESS (lb/in)	HIC	SLOPE (lb/in)	INTERCEPT (lb)
CIVIC	SIDE ROOF RAIL	726	733	886	-150
	A-PILLAR (upper)	1092	1204	1485	-297
	A-PILLAR (lower)	1043	1183	1353	-247
	FRONT ROOF RAIL	892	803	1247	-266
MUSTANG	SIDE ROOF RAIL	1521	1316	2070	-288
	A-PILLAR (upper)*	1443	1871	2213	-480
	A-PILLAR (lower)	1656	1586	2326	-425
	FRONT ROOF RAIL	641	399	683	-41
MALIBU	SIDE ROOF RAIL	588	648	664	-83
	A-PILLAR (upper)	2557	2305	3754	-578
	A-PILLAR (lower)	2203	2215	3160	-503
	FRONT ROOF RAIL	631	589	1064	-365

* The cross-section here was an overlap joint (i.e. double thickness sheet metal).

Table 7.3 Cont.
STRUCTURAL STIFFNESS vs. HIC

VEHICLE	STRUCTURE	STIFFNESS (lb/in)	HIC**	SLOPE (lb/in)	INTERCEPT (lb)
GRANADA	SIDE ROOF RAIL	838	812	1244	-340
	A-PILLAR (upper)*	2792	2623	4192	-601
	A-PILLAR (lower)	1570	1491	2259	-394
	FRONT ROOF RAIL	777	756	935	-138
HORIZON	B-PILLAR	1036	996	1496	-372
	SIDE ROOF RAIL	1197	1145	1654	-350
	A-PILLAR (upper)	1539	1462	2290	-497
	A-PILLAR (lower)	1039	998	1350	-265
	FRONT ROOF RAIL	947	913	1232	-181

* The cross-section here was an overlap joint (i.e. double thickness sheet metal).

** The HIC values listed here were calculated using the relationship presented in section 8.2.

Figures 7.3 through 7.9 are force vs. deflection plots of the various interior structures tested on each vehicle. The results of the Phoenix middle A-pillar tests are not shown here since they were very similar to the lower A-pillar results for that car. Again, the stiffness, slope, and intercept values listed in Table 7.3 were calculated using the "rising" portion of these curves.

The terms upper, middle, and lower which have been used to describe the various locations on the A-pillar are relative terms. The upper locations were in fact very near the roof (two to three inches). The lower locations, though, were the lowest point on each pillar that could be struck by the impactor. These points were actually near the center of the roof to cowl span. The middle location tested on the Phoenix was a point midway between the upper and lower locations described above.

The cross-sectional shapes of the vehicle structures tested with the head impactor are documented in Appendix B. The arrow on each of these photographs indicates the direction and location of impact.

7.4 Exterior Door Crushes

At least one exterior door crush was done for each of the cars. Figure 7.10 displays force vs. deflection plots of these crushes for the seven vehicles. Table 7.4 lists the stiffness, peak force, and maximum deflection for each of the exterior door crushes.

8.0 ANALYSIS AND SIGNIFICANCE OF STIFFNESS MEASUREMENTS

One of the objectives of this project was to determine the significance of the measured variations in the stiffness characteristics of the various structures. To accomplish this, an attempt was made to relate injury to the measured stiffness characteristics. This chapter describes the results of this effort for both the door area and upper interior component tests.

8.1 Door Area/Exterior Door Crushes

There were several goals for the tests done with the thoracic impactors. One was to determine if a simple test, such as that using the rigid thorax, could predict the

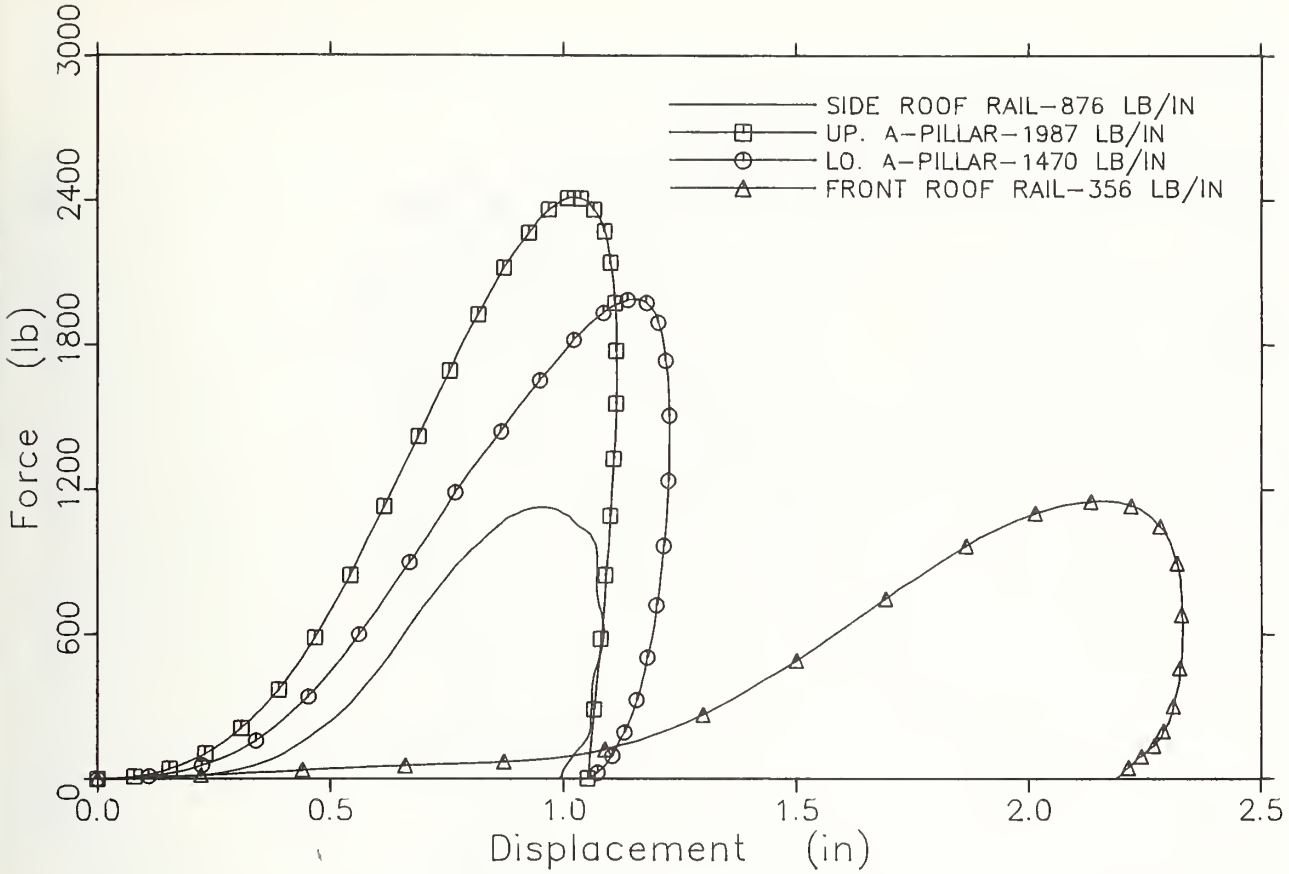


FIGURE 7.3. RABBIT INTERIOR STRUCTURES

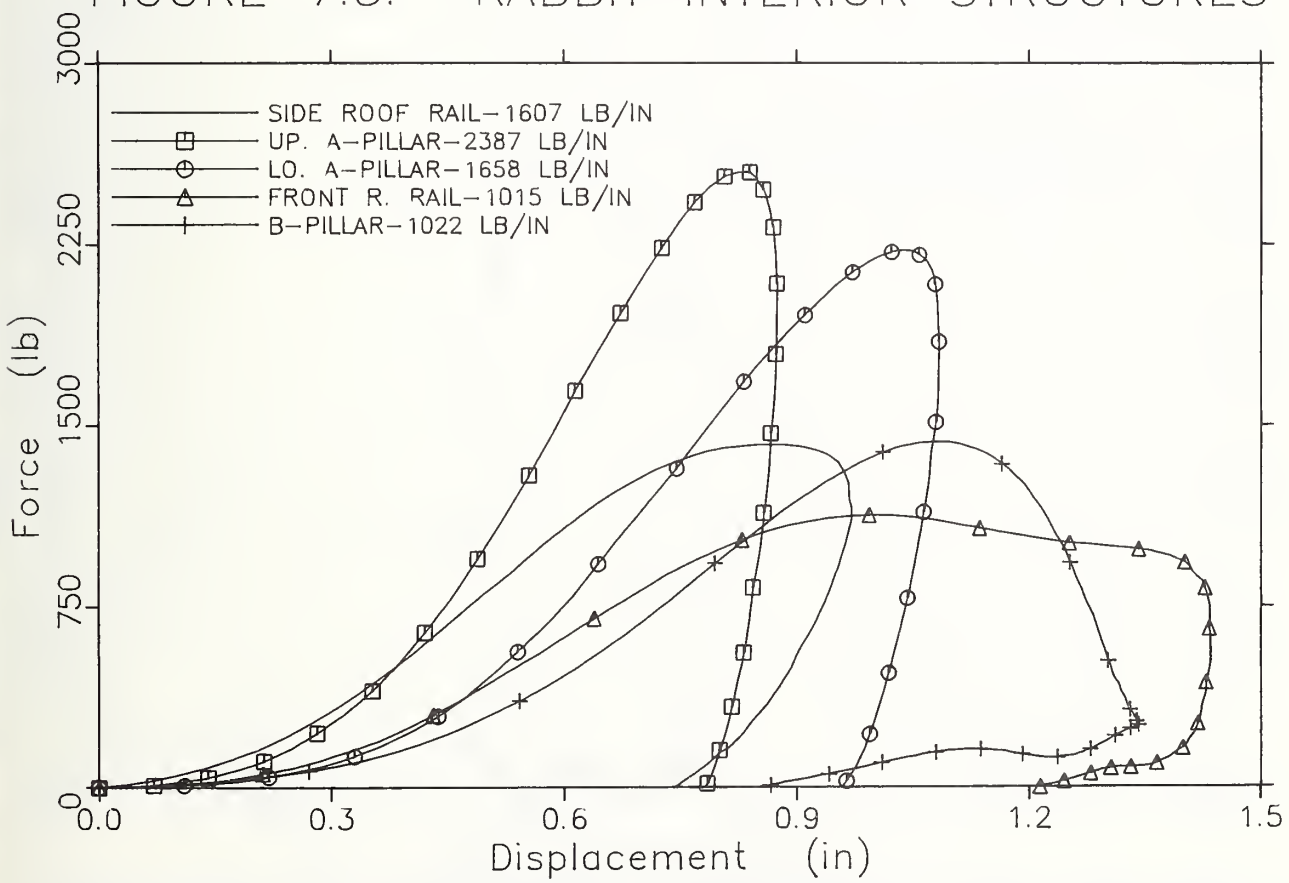


FIGURE 7.4. PHOENIX INTERIOR STRUCTURES

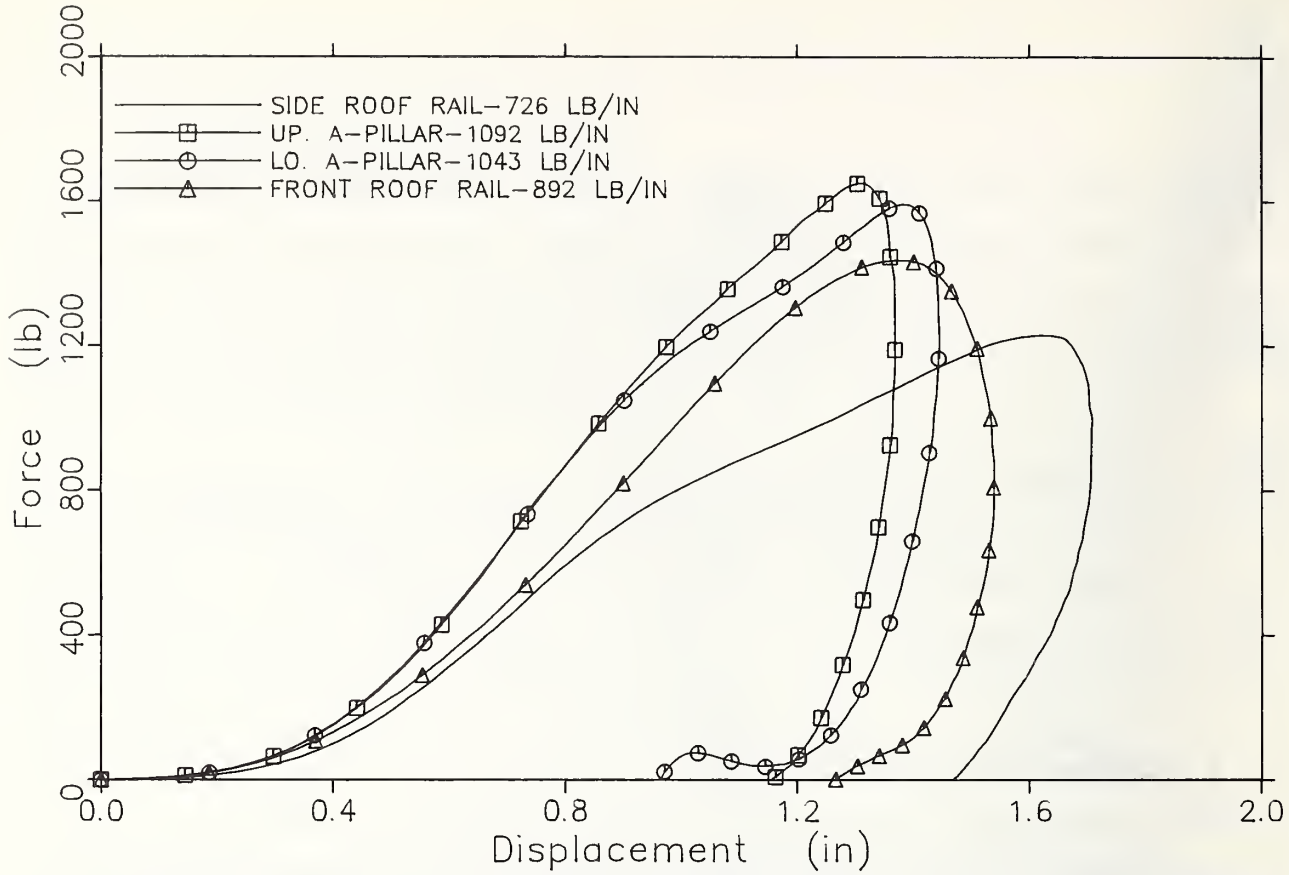


FIGURE 7.5. CIVIC INTERIOR STRUCTURES

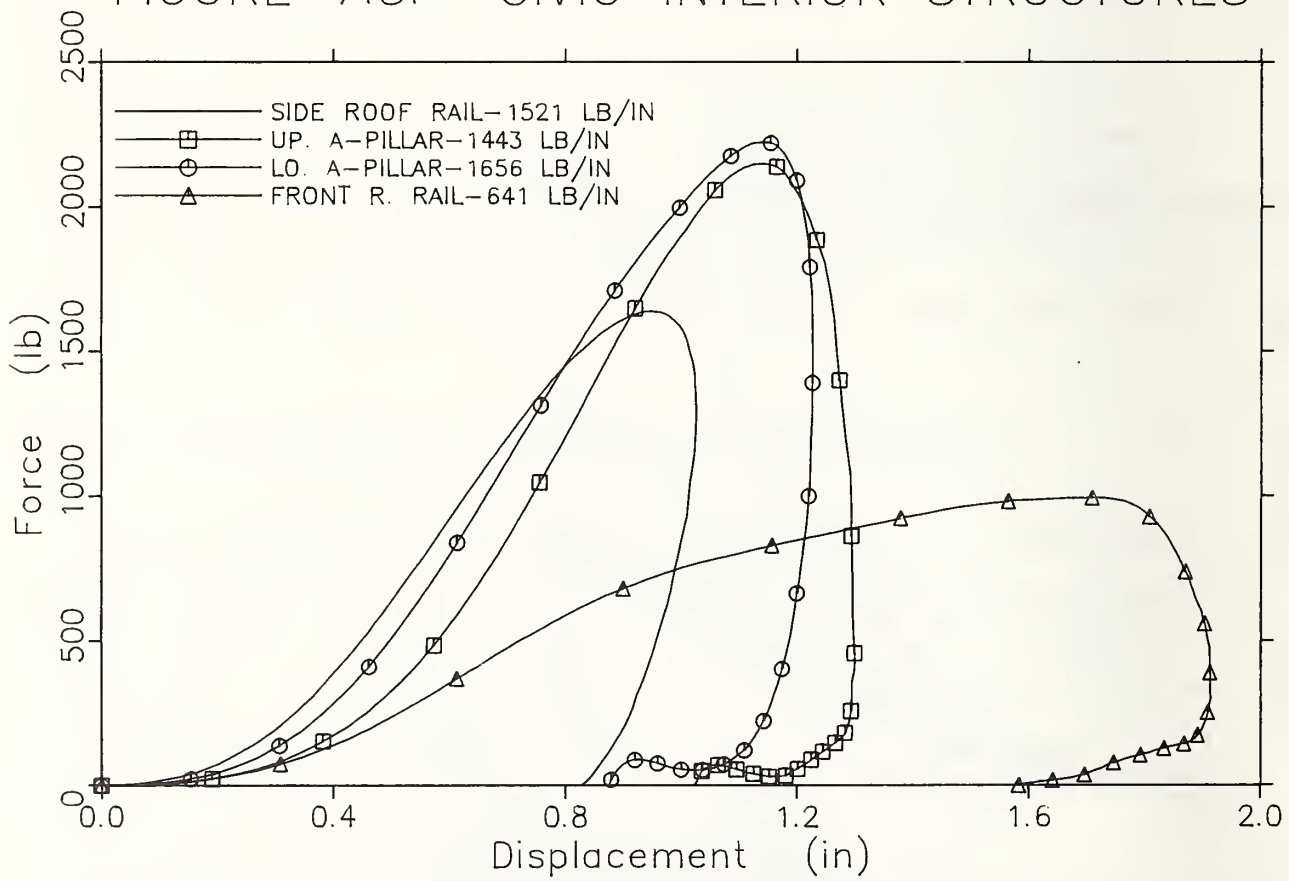


FIGURE 7.6. MUSTANG INTERIOR STRUCTURES

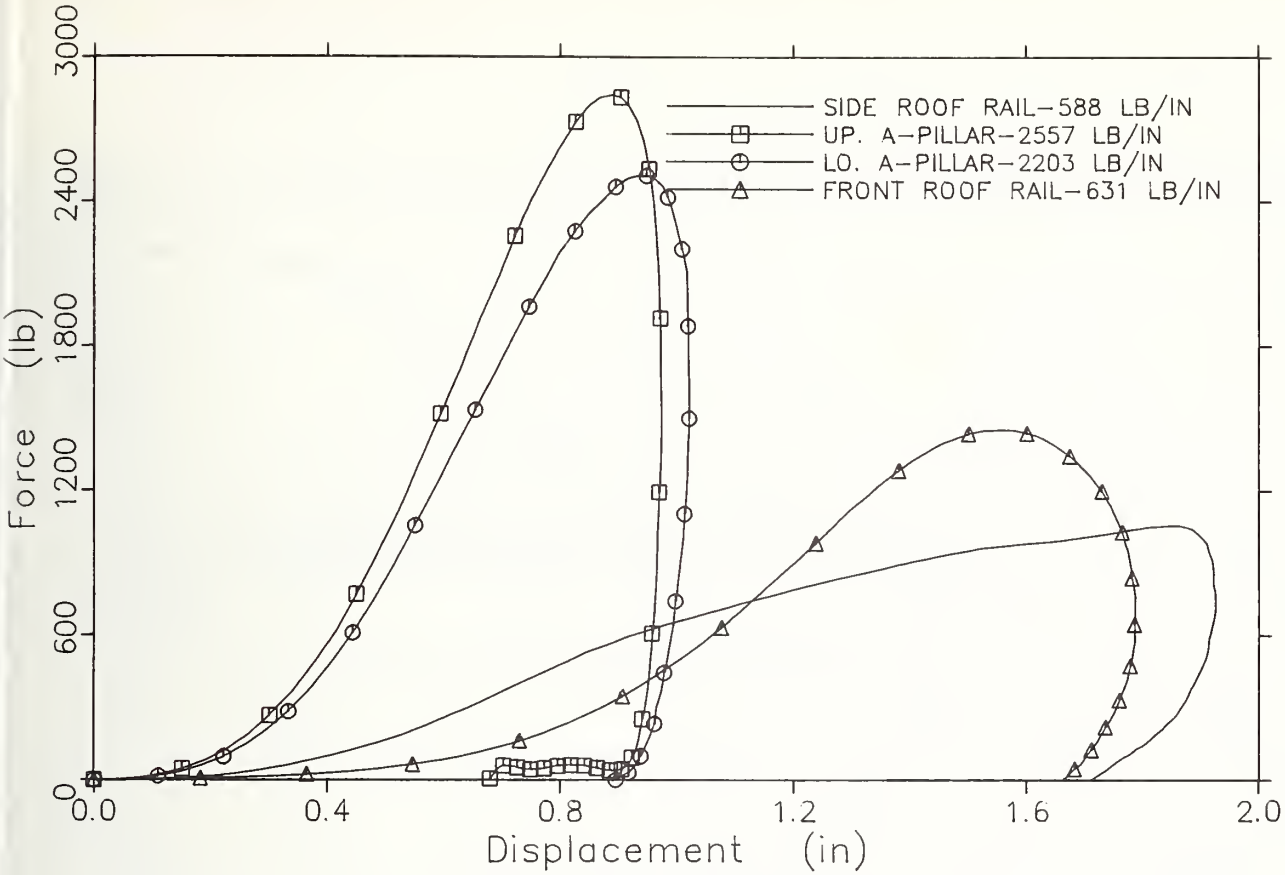


FIGURE 7.7. MALIBU INTERIOR STRUCTURES

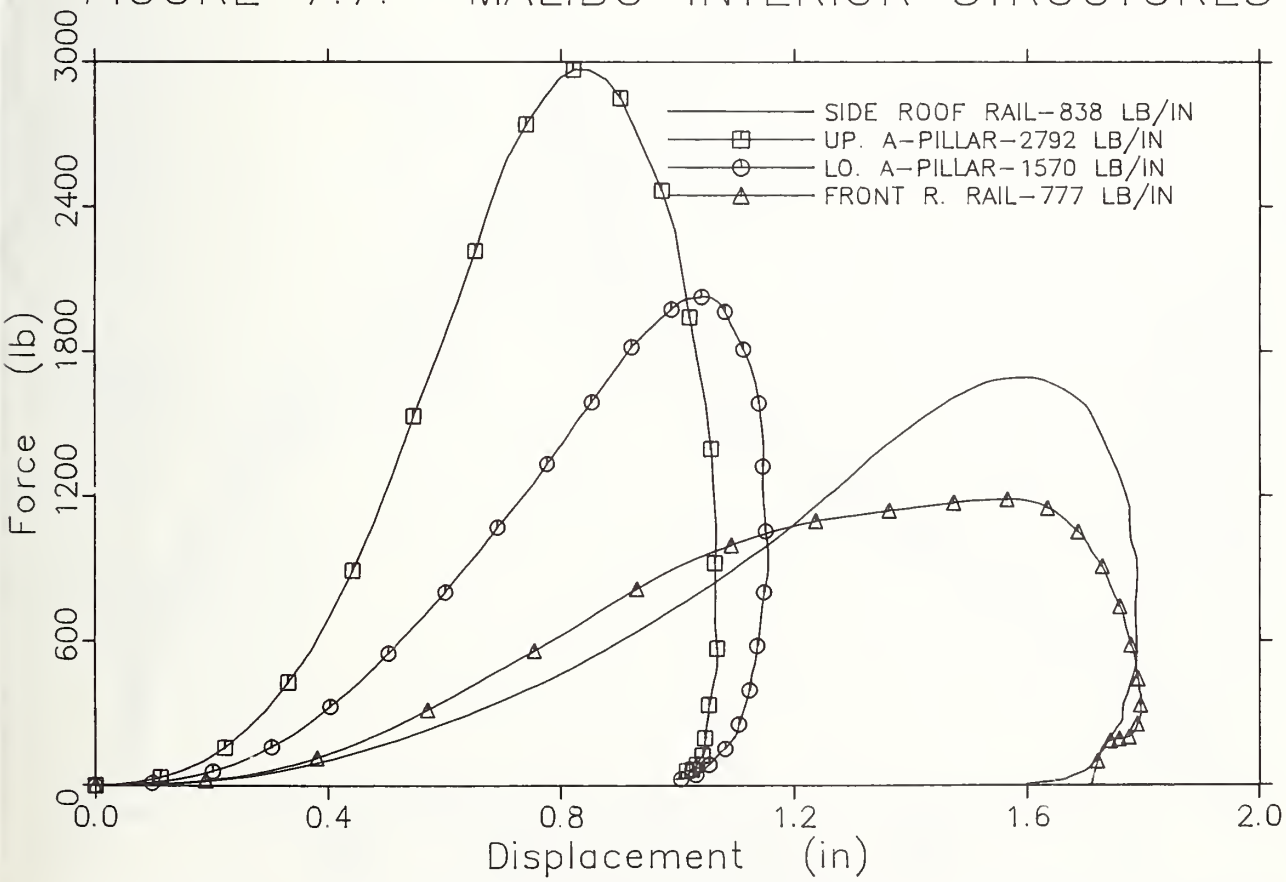


FIGURE 7.8. GRANADA INTERIOR STRUCTURES

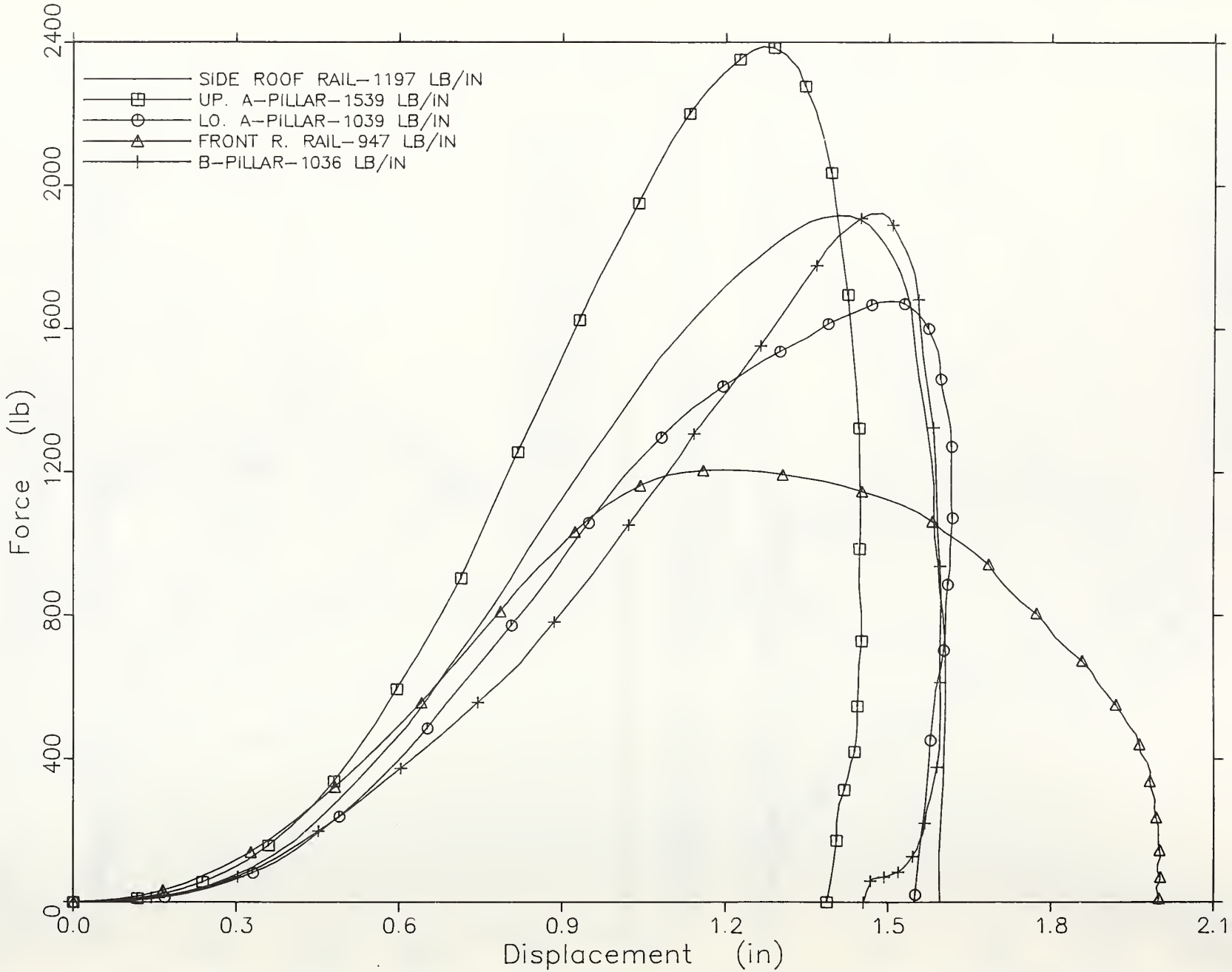


FIGURE 7.9. HORIZON INTERIOR STRUCTURES

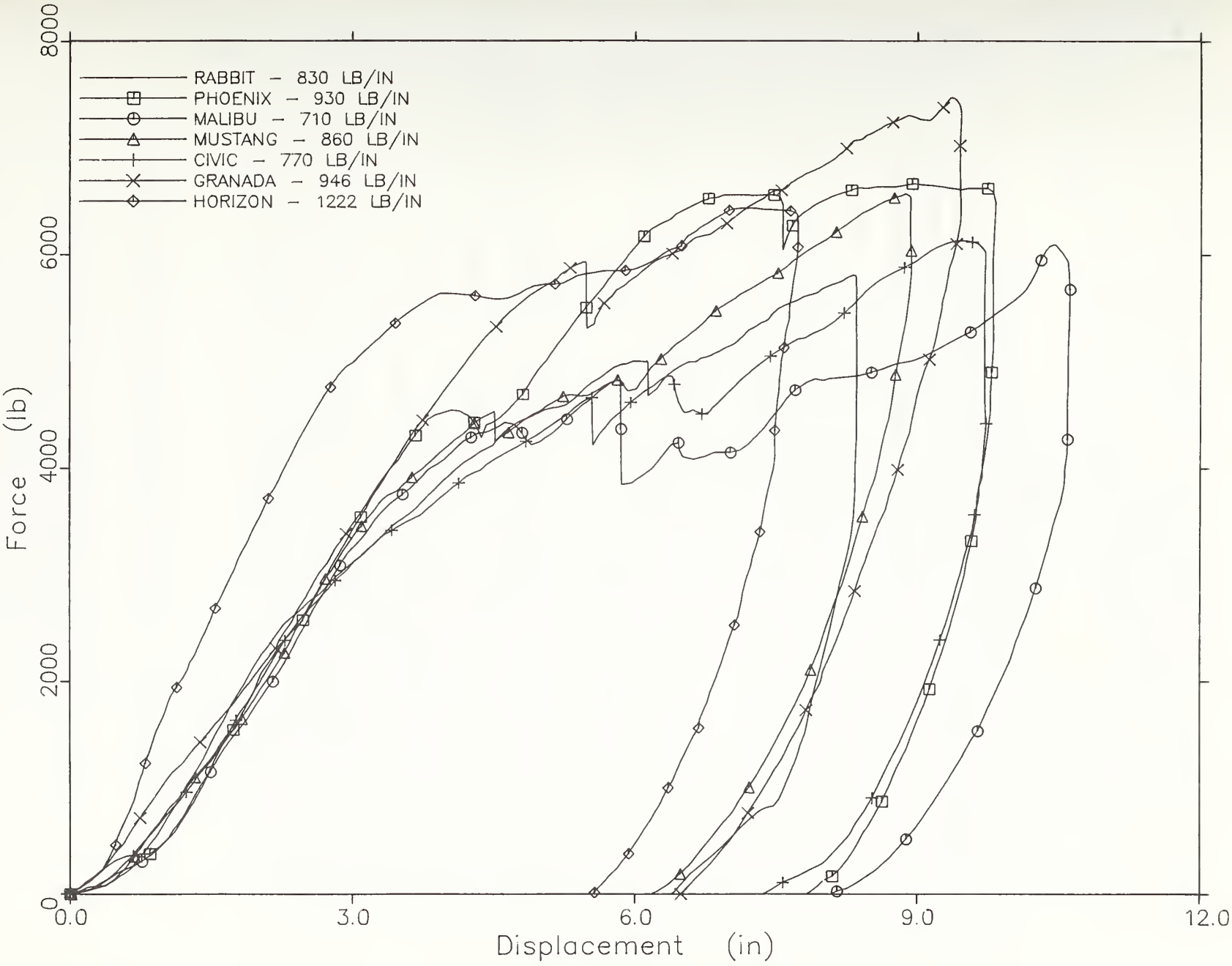


FIGURE 7.10. EXTERIOR DOOR CRUSHES

Table 7.4

EXTERIOR DOOR CRUSH RESULTS

VEHICLE	STIFFNESS (lb/in)	PEAK FORCE (lb)	MAXIMUM DEFLECTION (in)
RABBIT	830	5800	8.4
CIVIC	770	6100	9.7
PHOENIX	930	6700	9.8
MUSTANG	860	6700	8.9
MALIBU	710	6100	10.6
GRANADA	946	7500	9.5
HORIZON	1222	6400	7.7

results of a test with more biofidelity, and complexity, such as that using the SID thorax. Another was to determine if the stiffness characteristics measured in the component tests could predict injury potentials similar to those predicted from full system crash tests.

The Statistical Analysis System (SAS) was used to find linear models which related the desired dependent variables to a number of possible independent variables using stepwise regression. The independent variables were found from the dynamic rigid thorax tests, the static exterior crush tests, and various vehicle specifications. Those found from the dynamic tests included calculated stiffnesses and measured forces at 1.5, 2.0, 2.5, and 3.0 inches of deflection, as well as stiffness to peak force. The static crush tests gave peak crush force and the crush stiffness to peak force. Other possible independent variables included vehicle and door weights, maximum door thickness, and door thickness three inches below the window level. These thicknesses were metal to metal measurements, not including the thicknesses of interior door panels. Appendix A contains abbreviations and values for these variables for all the door area tests performed.

Three sets of dependent variables were used in the attempt to correlate SID thorax responses to rigid thorax measurements. These were the average rib acceleration, the maximum (upper or lower) rib acceleration, and the average spinal acceleration. Two sets of models were found from this effort, one for crushed door tests, the other for unbacked door tests. The number of independent variables used in each set of models was determined by the marginal increase in correlation for each case. For example, for the crushed door tests, a large increase in correlation occurred as the number of independent variables was raised to three. If this number was raised to four, much less increase was noted. Therefore, three independent variable models were used for these tests.

The STEPWISE routine produced the following results for the crushed door tests:

$$XRA = 0.0620\,(F15) - 0.812\,(DRWT) - 0.1017\,(PCS) + 121.4$$

Coefficient of determination, $r^2 = 0.96$

Significance level, SL = 1.47%

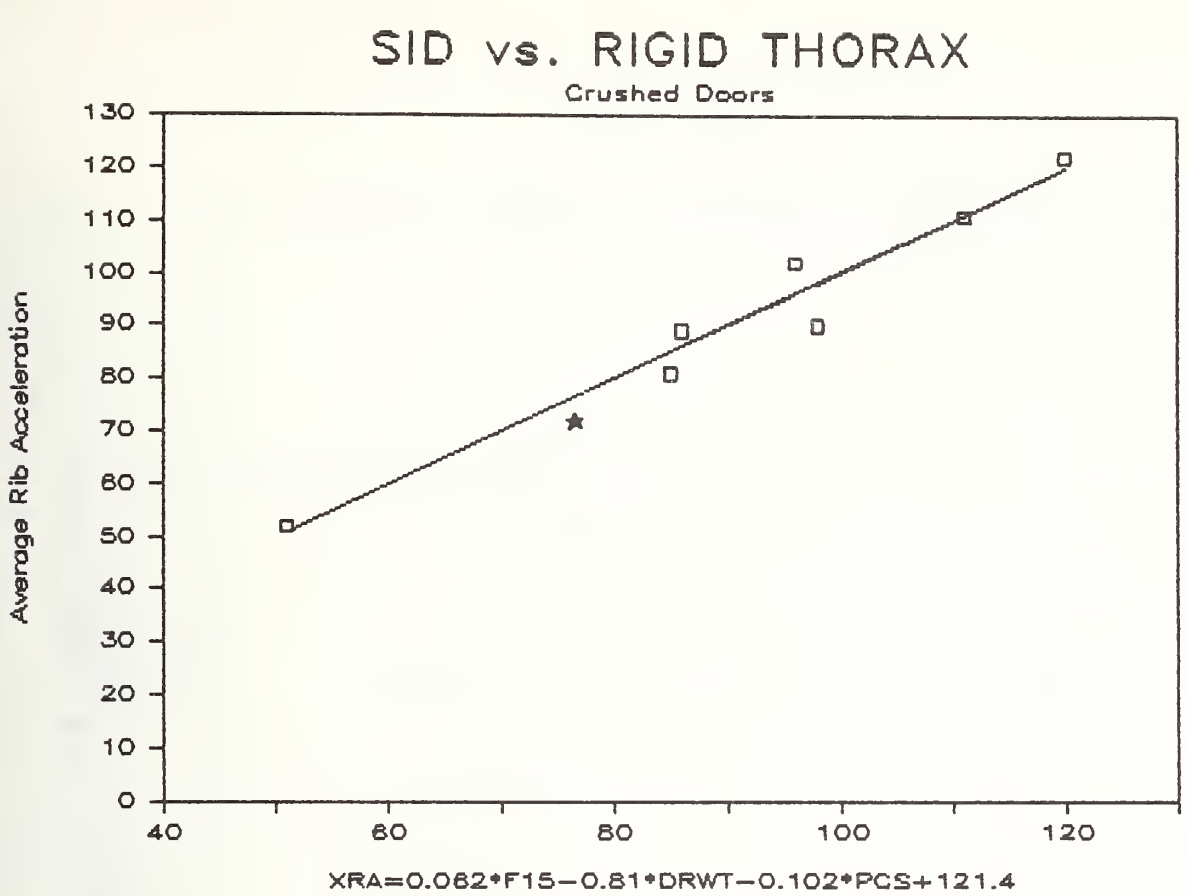
$$XRM = 0.0621\,(F15) - 1.007\,(DRWT) - 0.1241\,(PCS) + 161.1$$
$$r^2 = 0.95 \quad SL = 1.65\%$$

$$XSA = 0.0497\,(SP) - 0.0108\,(F25) - 0.161\,(DRWT) + 52.8$$
$$r^2 = 0.98 \quad SL = 0.31\%$$

The terms XRA, XRM, and XSA are the predicted average rib, maximum rib, and average spinal accelerations, respectively. F15 and F25 are the measured forces at 1.5 and 2.5 inches of deflection. SP is the stiffness up to peak force found from the dynamic tests while PCS is the static crush stiffness up to peak force. DRWT is the weight of the door.

Figures 8.1 and 8.2 show plots of the functions listed above as well as of the actual data. For the actual data, the horizontal axes are the values predicted by the models while the vertical axes are the responses measured in the SID thorax tests. An additional vehicle, a Volkswagen Rabbit with added door padding, was tested in the crushed door mode in an attempt to produce some validation of the models. The starred points on the plots represent the results from this vehicle. As can be seen, when the models were applied to the rigid thorax data of the padded Rabbit, they predicted the responses of the SID thorax very well. Detailed results of this test are contained in Appendix A.

The influence that each independent variable has on the predicted response of each model was also examined. This was done using the range of each variable as well as its model coefficient. For example, the above model for XRA has three independent variables, F15, DRWT, and PCS. On the eight vehicles tested, these varied by 766 lbs, 36 lbs, and 512 lb/in, respectively. Multiplying each of these variations by its appropriate coefficient, it was found that the individual maximum influences these could have on the dependent variable were 48g, 29g, and 52g, respectively. The combined maximum influence, then, was 129g. The ratios of the individual influences to the combined influence were taken to be the sensitivities of the dependent to each of the independent variables. In this case they were 37%, 23%, and 40%. Table 8.1 lists the independent variables, their variations, maximum influences, and sensitivities for each of the three models presented above. Also included in the table is the actual range for the dependent variable of each model.


SID vs. RIGID THORAX
Crushed Doors
Average Rib Acceleration
130
120
110
100
90
80
70
60
50
40
30
20
10
0
40
60
80
100
120
XRA=0.062*F15-0.81*DRWT-0.102*PCS+121.4

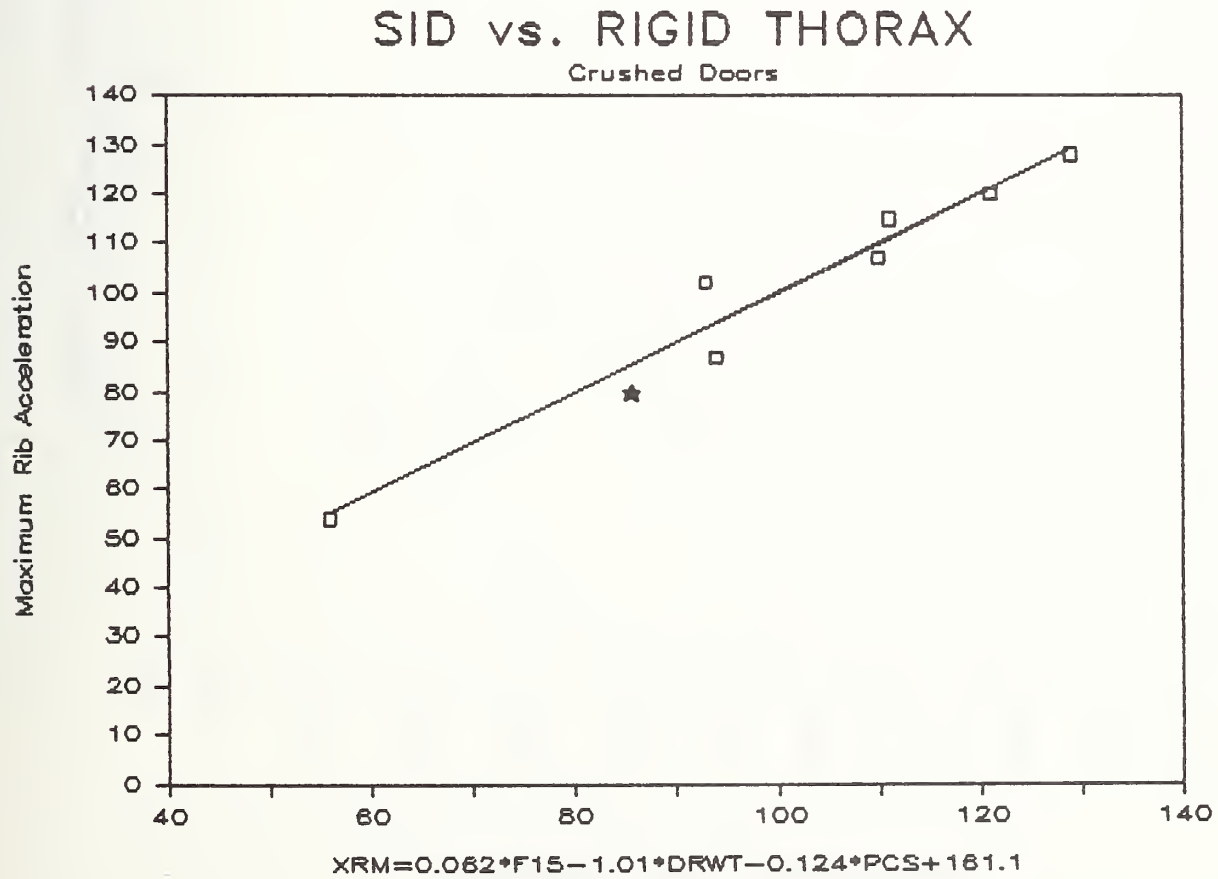

SID vs. RIGID THORAX
Crushed Doors
Maximum Rib Acceleration
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
40
60
80
100
120
140
XRM=0.062*F15-1.01*DRWT-0.124*PCS+161.1

Figure 8.1

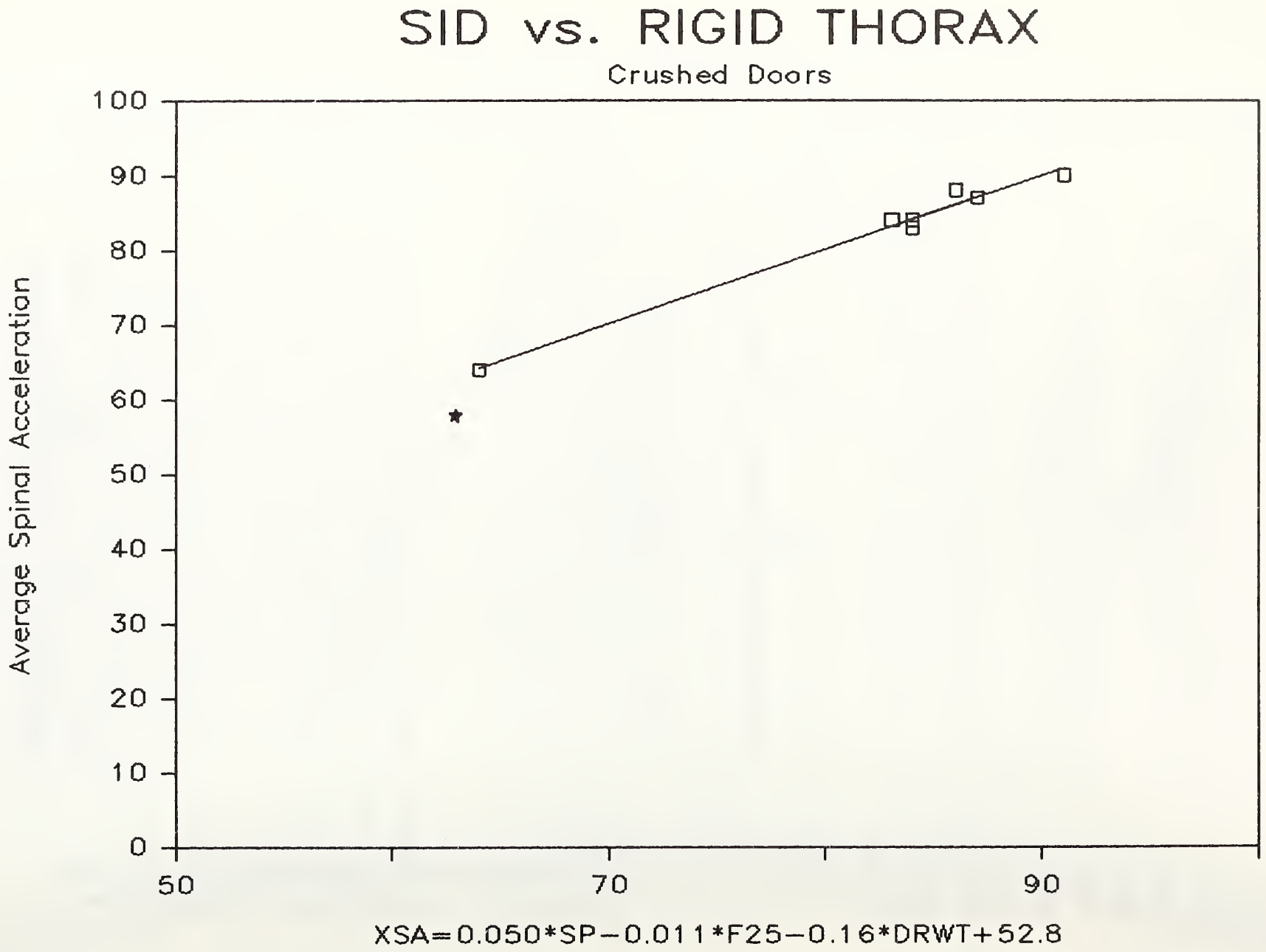

SID vs. RIGID THORAX
Crushed Doors
Average Spinal Acceleration
100
90
80
70
60
50
40
30
20
10
0
50
70
90
XSA=0.050*SP-0.011*F25-0.16*DRWT+52.8

Figure 8.2

TABLE 8.1

DEPENDENT TO INDEPENDENT VARIABLE SENSITIVITIES

Crushed Doors

Independent Variable	Variation		Maximum Influence	Sensitivity
XRA =>51 to 120g				
F15	766	lb	48g	37%
DRWT	36	lb	29g	23%
PCS	512	lb/in	52g	40%
XRM =>56 to 129g				
F15	766	lb	48g	32%
DRWT	36	lb	36g	25%
PCS	512	lb/in	64g	43%
XSA =>63 to 91g				
SP	1223	lb/in	61g	58%
F25	3565	lb	39g	37%
DRWT	36	lb	6g	5%

A similar regression was performed on the data from the unbacked door tests. These results were as follows:

$$XRA = 0.0259\,(F15) + 0.980\,(DRWT) - 22.1$$
$$r^2 = 1.00 \quad SL = 0.39\%$$

$$XRM = 0.0284\,(F15) + 1.029\,(DRWT) - 23.5$$
$$r^2 = 1.00 \quad SL = 0.24\%$$

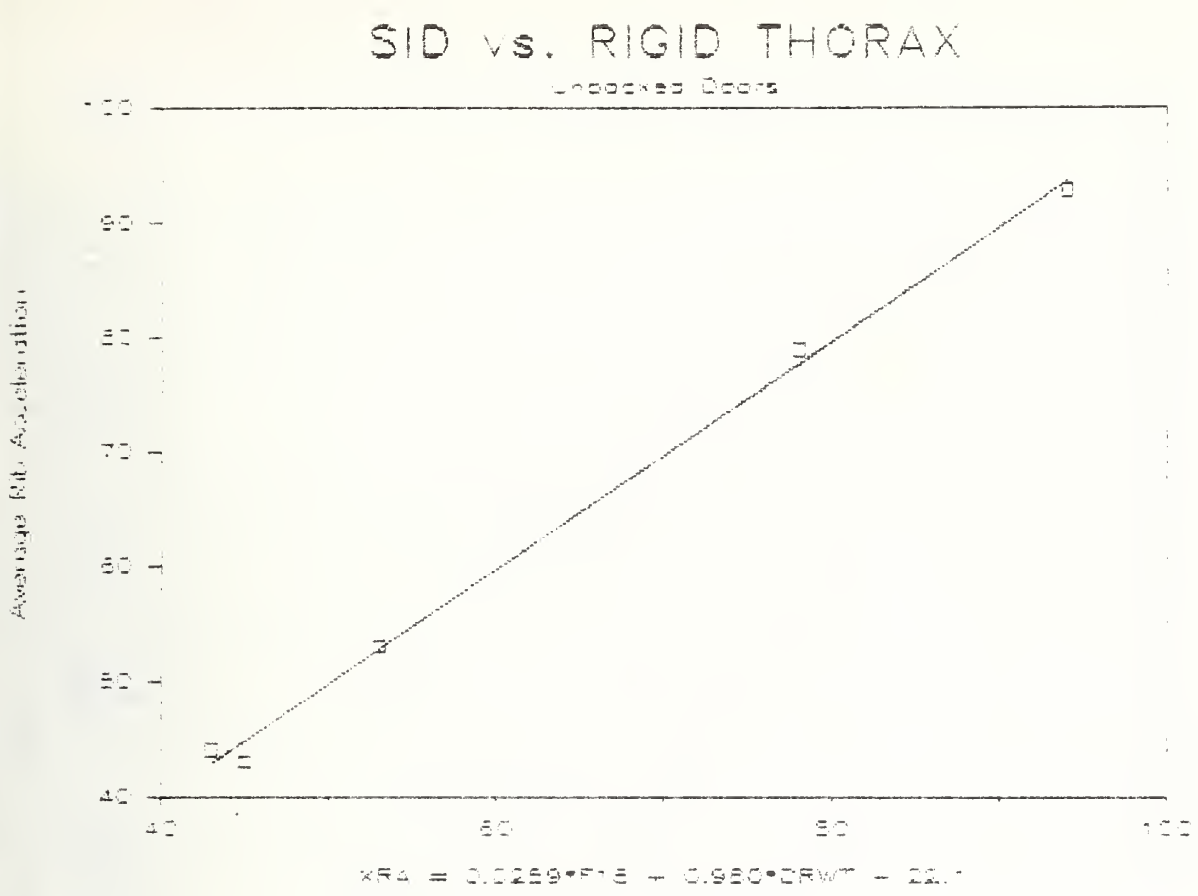
$$XSA = 0.0109\,(F25) - 0.0088\,(F30) + 37.3$$
$$r^2 = 0.96 \quad SL = 4.30\%$$

F15, F25, and F30 are the forces measured during the rigid thorax tests at 1.5, 2.5, and 3.0 inches of deflection, respectively. As before, DRWT is the weight of the door. Figures 8.3 and 8.4 show plots of the functions listed above as well as of the actual data. Table 8.2 contains the dependent to independent variable sensitivities for these models. Since this test mode produced relatively low levels of response from the SID thorax, no further investigation was done. Therefore, no additional vehicle was tested to provide validation of the models.

When the manner in which the independent variables affect the dependent variable of each model was examined, the results were intuitively satisfying. As the loads and stiffnesses on the thorax increased, the predicted accelerations increased. The exceptions to this were that in each spinal acceleration model, the response decreased as a force increased. This may be a valid adjustment in cases such as this, where the dynamic forces and stiffnesses are not truly independent of each other.

Terms such as DRWT and PCS were indications of door size and pliancy. In the crushed door tests, the door acted as an interface between the thorax and the honeycomb. For these, a more substantial door provided more cushion than a lesser door against the stiffer honeycomb. Therefore, as these values increased, predicted accelerations decreased.

For the unbacked door tests, the opposite was true. Since there was no honeycomb present, the larger doors produced higher accelerations than the smaller doors. This was reflected in the models.


SID vs. RIGID THORAX
Unbelted Dogs
Average Rib Acceleration
40
60
80
100
XR4 = 0.0289*F15 + 0.980*DRWT - 22.1

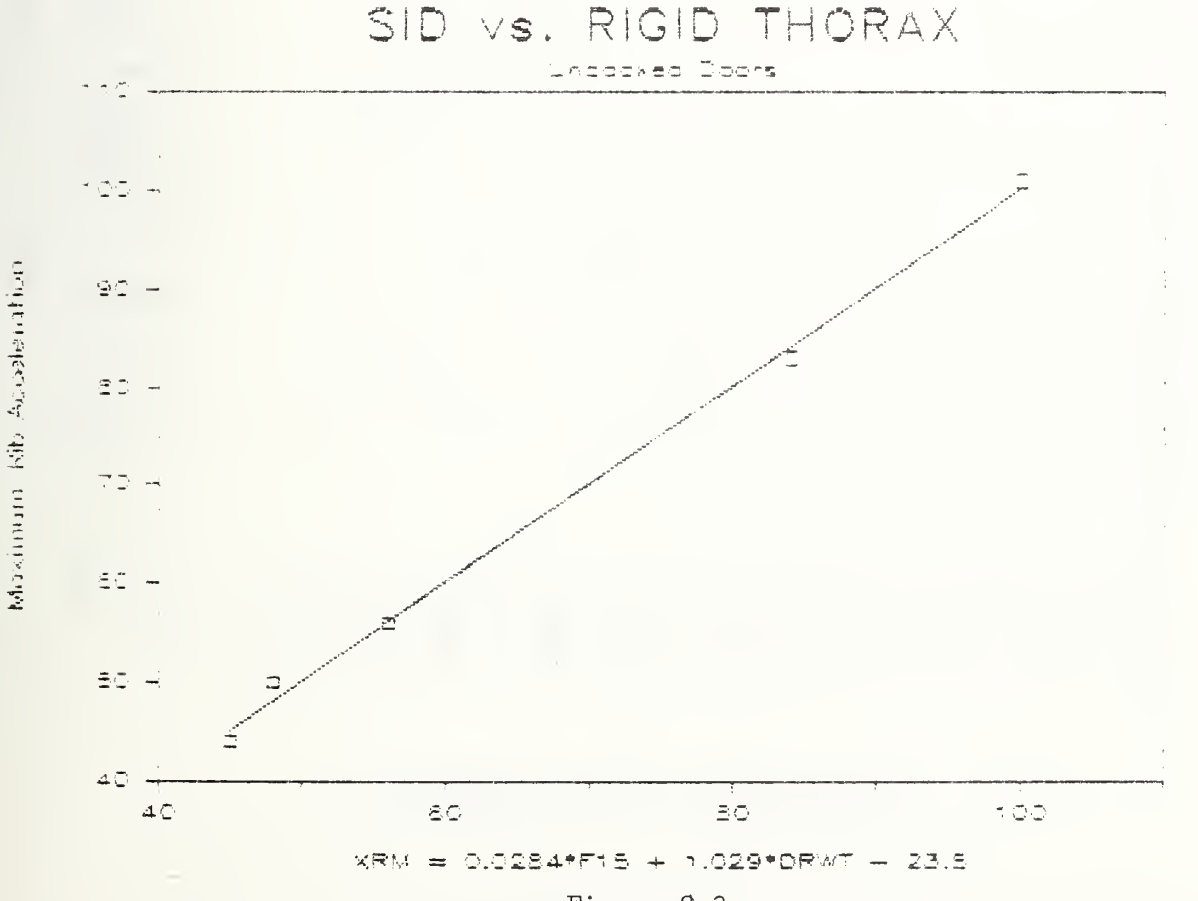

SID vs. RIGID THORAX
Unbelted Dogs
Maximum Rib Acceleration
40
60
80
100
XRM = 0.0284*F15 + 1.029*DRWT - 23.8

Figure 8.3

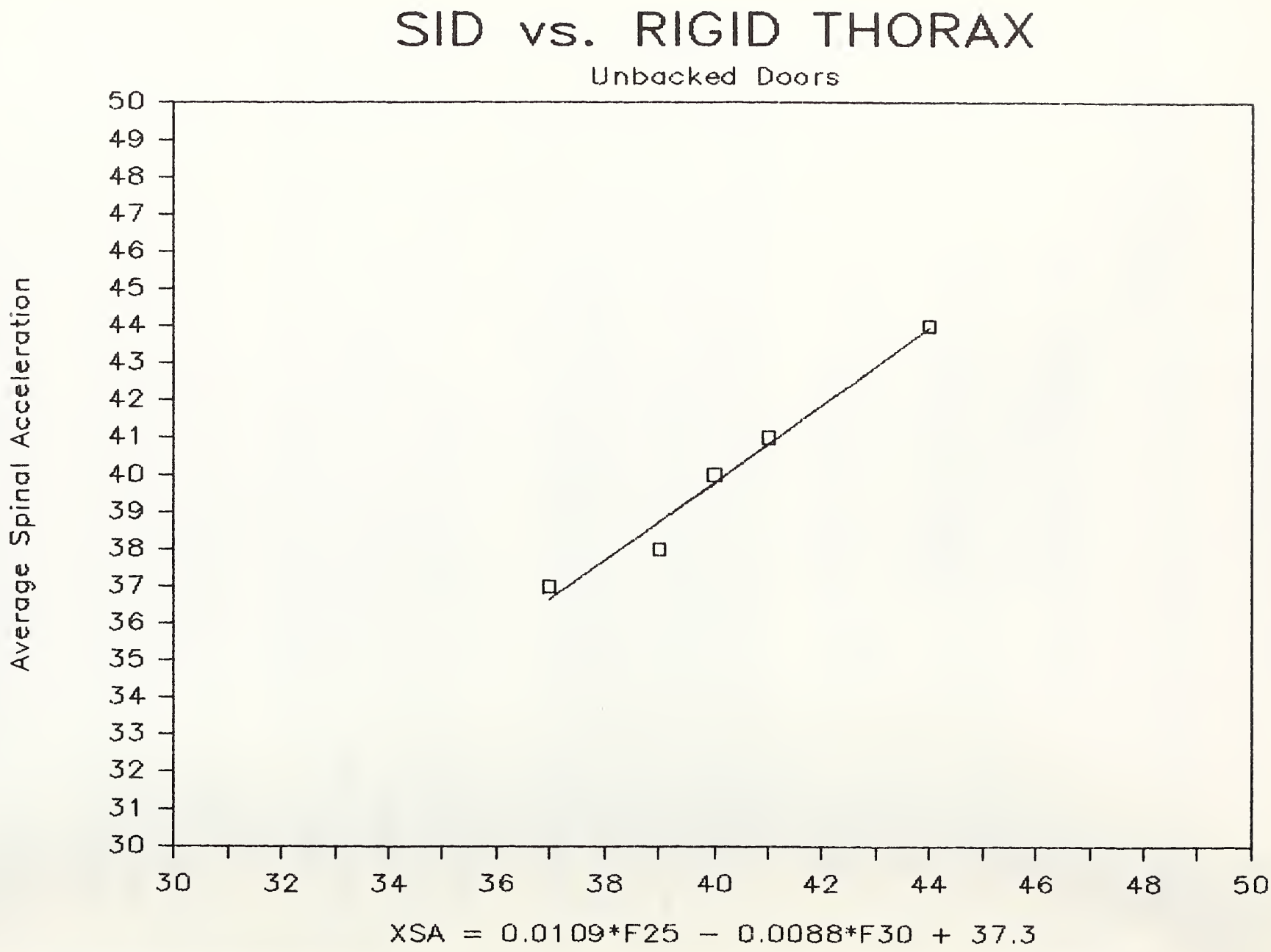

SID vs. RIGID THORAX
Unbacked Doors
Average Spinal Acceleration
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
30
32
34
36
38
40
42
44
46
48
50
XSA = 0.0109*F25 - 0.0088*F30 + 37.3

Figure 8.4

TABLE 8.2

DEPENDENT TO INDEPENDENT VARIABLE SENSITIVITIES

Unbacked Doors

Independent Variable	Variation	Maximum Influence	Sensitivity
	XRA =>43 to 94g		
F15	1908 lb	49g	58%
DRWT	36 lb	35g	42%
	XRM =>45 to 100g		
F15	1908 lb	54g	59%
DRWT	36 lb	37g	41%
	XSA =>37 to 44g		
F25	1383 lb	15g	55%
F30	1423 lb	13g	45%

Another goal of these tests was to determine if the stiffness characteristics measured in the rigid thorax component tests could predict injury potentials that were similar to those predicted in the crash tests. Four of the vehicles that had been component tested in the crushed door mode had also been crash tested under project SRL-91. The crash tests were done using the MDB, simulating 90° impacts with striking/struck velocities of 30/15 mph.

The independent variables used for this modeling were obtained from the rigid thorax tests as before. The dependent variables used were derived from the driver responses of the crash tests. The injury index adopted for the NHTSA's thoracic side impact research (2) is a probability of receiving an injury of a given AIS level. A value for an intermediate function is first calculated based upon rib and spinal responses as well as age. This value is then transformed into a probability. Since linear regressions were to be performed and the probability functions are non-linear, the dependent variables used in this regression were these intermediate function values and not the probabilities.

This intermediate function (IFV) is as follows:

$$IFV = 0.5\,(RIB + SPINE) + 1.4\,(AGE)$$

Since AGE is not an outcome of the crash tests and is held constant for a set of injury calculations, it was set to zero for this regression. The values for SPINE used were the average of the upper and lower spinal accelerations. Two sets of values for RIB were used, which were the adjusted (2)* maximum and adjusted average rib accelerations. Therefore, two dependent variables were used in the stepwise regression, one an average of maximum rib and average spinal responses and one an average of average rib and average spinal responses.

Once again, the STEPWISE routine was used and it produced the following results:

$$RIBSPM = 0.0366\,(S15) - 0.0280\,(VW) + 122.2$$
$$r^2 = 0.99 \quad SL = 7.6\%$$

$$RIBSPA = 0.0308\,(S15) - 0.0256\,(VW) + 119.8$$
$$r^2 = 0.98 \quad SL = 13.7\%$$

*Adjusted rib acceleration, RIB = 0.5 (Ribg) + 30 when Ribg >60.

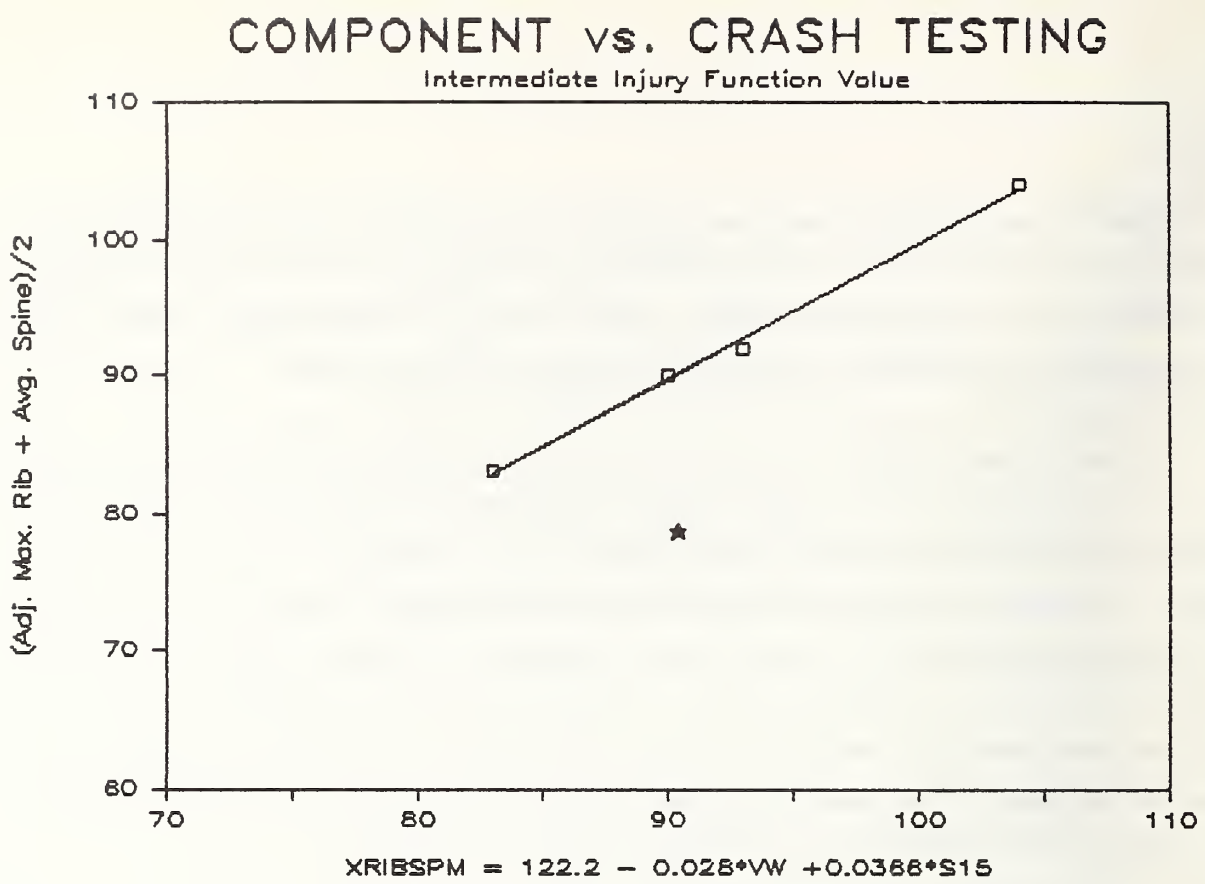
RIBSPM and RIBSPA are the predicted intermediate function values using maximum rib and average rib accelerations, respectively. S15 is the calculated stiffness at 1.5" of dynamic deflection, while VW is the vehicle weight. Table 8.3 lists the dependent to independent variable sensitivities for these models.

Figure 8.5 shows plots of the functions listed above as well as of the actual data. For the actual data, the horizontal axes are the values predicted by the models and the vertical axes are the intermediate function values calculated from the crash test dummy responses. A 4-door Honda Civic had been crash tested as part of project SRL-91. In an attempt to provide some validation of these models, a rigid thorax component test was also performed on it. The starred points on these plots represent the results of the Civic tests. As can be seen, when the models were applied to the rigid thorax data of the 4-door Civic, both overestimated the severity of the crash test by margins of 14%. Detailed results are contained in Appendix A.

TABLE 8.3

DEPENDENT TO INDEPENDENT VARIABLE SENSITIVITIES
Crash/Component Tests

Independent Variable	Variation	Maximum Influence	Sensitivity
	RIBSPM = 83 to 104g		
S15	1146 lb/in	42g	53%
VW	1328 lb	37g	47%
	RIBSPA = 81 to 100g		
S15	1146 lb	35g	51%
VW	1328 lb	34g	49%


COMPONENT vs. CRASH TESTING
Intermediate Injury Function Value
(Adj. Max. Rib + Avg. Spine)/2
110
100
90
80
70
60
70
80
90
100
110
XRIBSPM = 122.2 - 0.028*VW +0.0366*S15

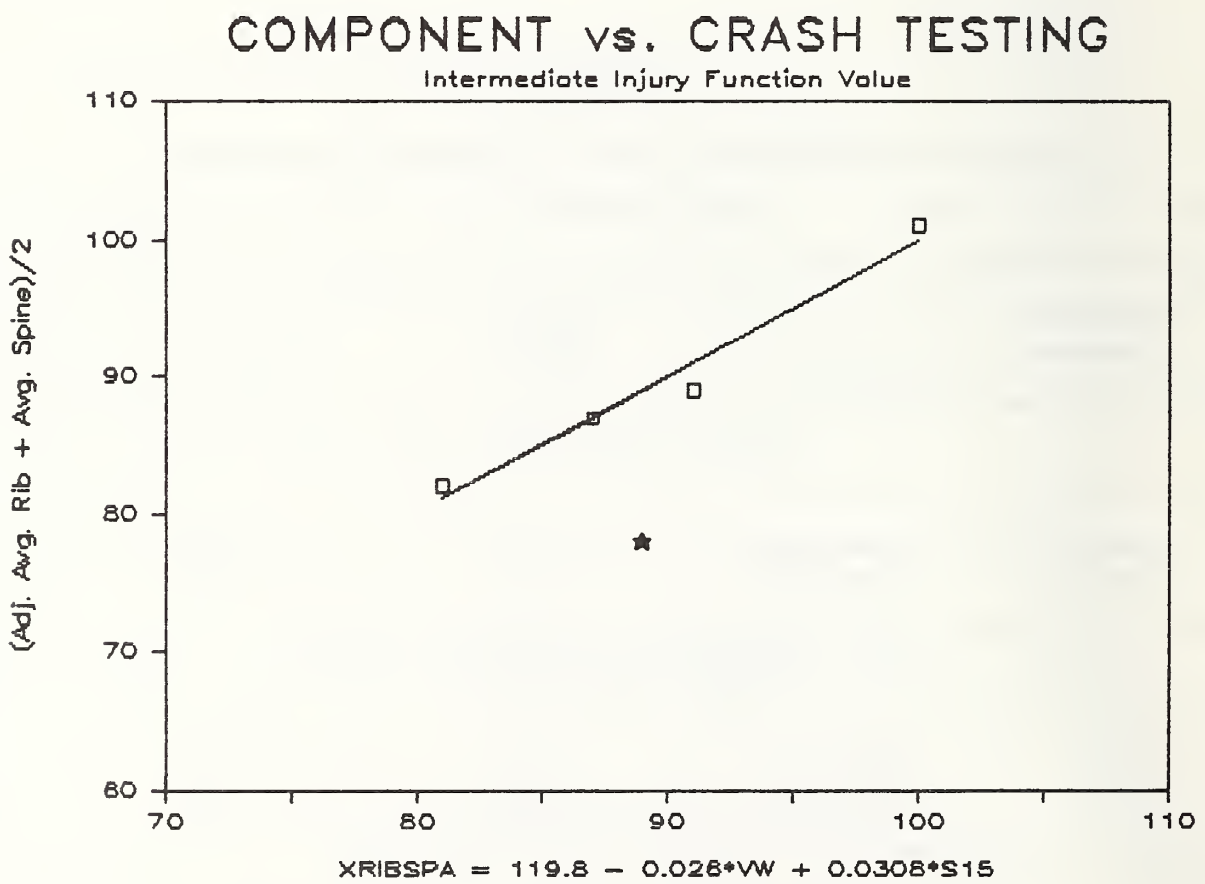

COMPONENT vs. CRASH TESTING
Intermediate Injury Function Value
(Adj. Avg. Rib + Avg. Spine)/2
110
100
90
80
70
60
70
80
90
100
110
XRIBSPA = 119.8 - 0.026*VW + 0.0308*S15

Figure 8.5

All of the models presented in this secton were based upon a small number of samples. Therefore, the observations and conclusions are viewed as tentative. It is not known if additional data will follow the same trends. The intent was to investigate the prospect for developing models that would predict the results of a complex test using the results of a much simpler test.

8.2 Upper Interior

Similar to the door area component tests, a rigid headform was used to measure the stiffness characteristics of upper interior structures of several vehicles. In addition, a more biofidelic headform, constructed from a Part 572 dummy head, was used to measure the resultant head accelerations that occured from impacts with these same structures. The results of these tests were used to correlate head injury to structural stiffness.

Figure 8.6 is a plot of the head injury criteria (HIC) versus the stiffness to peak forces (SP) for each of the structures tested. As can be seen, there was a definite trend of increasing HIC with increasing stiffness. A simple linear regression of these points produced the following model:

$$HIC = 0.927\,(SP) + 35.2$$
$$r^2 = 0.90$$

Because of the degree of correlation achieved with only one independent variable, a SAS analysis of multiple independent variables was not attempted for the head impact results.

9.0 FULL DUMMY TESTING OF UPPER INTERIOR

As mentioned in secton 6.1, it was necessary to compromise on the interior impact angles for the head component tests. The inability of the device to be positioned for

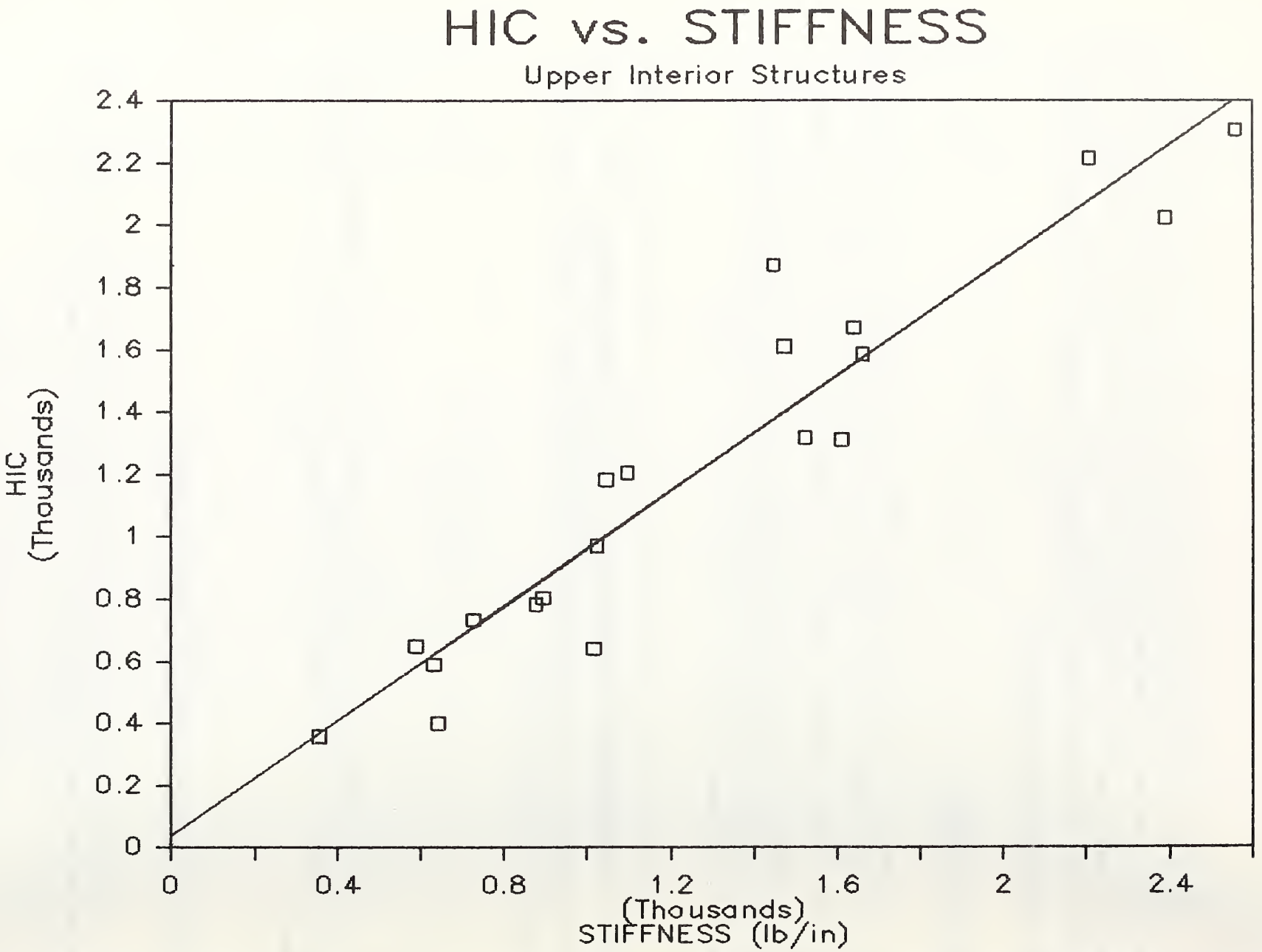

HIC vs. STIFFNESS
Upper Interior Structures
HIC (Thousands)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.4
0.8
1.2
1.6
2
2.4
(Thousands)
STIFFNESS (lb/in)

Figure 8.6

and measure the response of glancing impacts was a shortcoming of the procedure used. In an effort to determine the extent to which this was a problem, two sets of HYGE sled tests were performed. These utilized a full dummy and vehicle body to simulate head impacts in an accident.

9.1 Approach

The HYGE sled tests were done to simulate head to A-pillar impacts as would realistically occur in an accident. The dummy's head was to hit a point on the A-pillar about two inches below the front roof rail at speeds of 15 and 20 mph. To avoid interaction with the steering wheel/column, it was decided to simulate a front seat passenger (i.e. no steering wheel).

Sled bucks were built from two of the vehicles that had previously been component tested, the Chevrolet Citation (same structure as a Pontiac Phoenix) and the Volkswagen Rabbit. In order to contact the impact locations desired, the vehicles were mounted such that the line between the head and A-pillar was parallel to the direction of sled movement. To achieve this, the Citation was mounted on the sled at an angle of 45 degrees and the Rabbit at an angle of 22 degrees. In each case, the vehicle buck could be turned to allow testing to be done on both the right and the left sides.

Since the knees of the dummy usually damaged the dashboard, it was replaced between tests. Each dashboard was used for a right and a left side test. Similarly, if the windshield broke during a test, it was replaced prior to the next test. In addition, the interior door trim panels were damaged on the Citation buck and were therefore replaced between tests.

A Part 572 dummy was used in each of the tests. Accelerometers were mounted along the three axes in each of the head, chest and pelvis of the dummy. Force transducers were mounted in the femur of each leg and a displacement potentiometer was placed in the chest cavity. Each vehicle contained two accelerometers oriented fore to aft and side to side relative to the vehicle body. These were mounted on the rear deck of the Citation and on the floor tunnel of the Rabbit. Movement of the sled itself was measured by means of an accelerometer and a displacement potentiometer, both oriented in the direciton of the sled movement.

In addition to the above instrumentation, a 60" string potentiometer was also used to measure head displacement. It was mounted in a bracket behind the front seat and attached to the back of the dummy's head. The main objective of this device was to obtain a displacement/time curve of the dummy's head relative to the vehicle body. This curve could then be smoothed and differentiated to give head velocity as a function of time. Impact velocity could then be obtained.

9.2 Results

A total of nine sled tests were done, four with the Citation buck and five with the Rabbit buck. Tables 9.1 and 9.2 give a brief synopsis of each test. Appendix E contains more detailed results of these tests.

Table 9.1
CITATION SLED BUCK TESTS

TEST NUMBER	TEST CONDITIONS		HIC	COMMENTS
	NOMINAL VELOCITY	VEHICLE SIDE		
1	20 mph	right	917	- Head hit side roof rail first; too high - Buck unstable
2	20 mph	right	1679	- Head hit desired location on pillar - Buck unstable
3	20 mph	left	2384	- Head hit desired location on pillar - Buck stable
4	15 mph	left	799	- Head hit desired location on pillar - Buck stable

The Citation sled tests were done using the buck from a previous program, with the necessary modifications made (see figure 9.1). As the dummy normally sat in the front seat, its head was about 10 inches from the A-pillar. This meant that the buck was to be accelerated to 20 mph in under 10 inches, resulting in an acceleration of about 30g (for the 20 mph tests). As mentioned earlier, the body of the Citation was also mounted at an angle of 45 degrees to the direction of movement. All these factors combined to make the stabilization of the buck a problem.

Table 9.2
RABBIT SLED BUCK TESTS

TEST NUMBER	TEST CONDITIONS		HIC	COMMENTS
	NOMINAL VELOCITY	VEHICLE SIDE		
5	20 mph	right	624	- Head hit side roof rail first; too high - Buck stable
6	20 mph	right	1019	- Head hit desired location on pillar - Buck stable
7	20 mph	left	1076	- Head hit desired location on pillar - Buck stable
8	15 mph	left	448	- Head grazed wing window; hit pillar where desired
9	15 mph	left	415	- Removed wing window - Head hit desired location on pillar

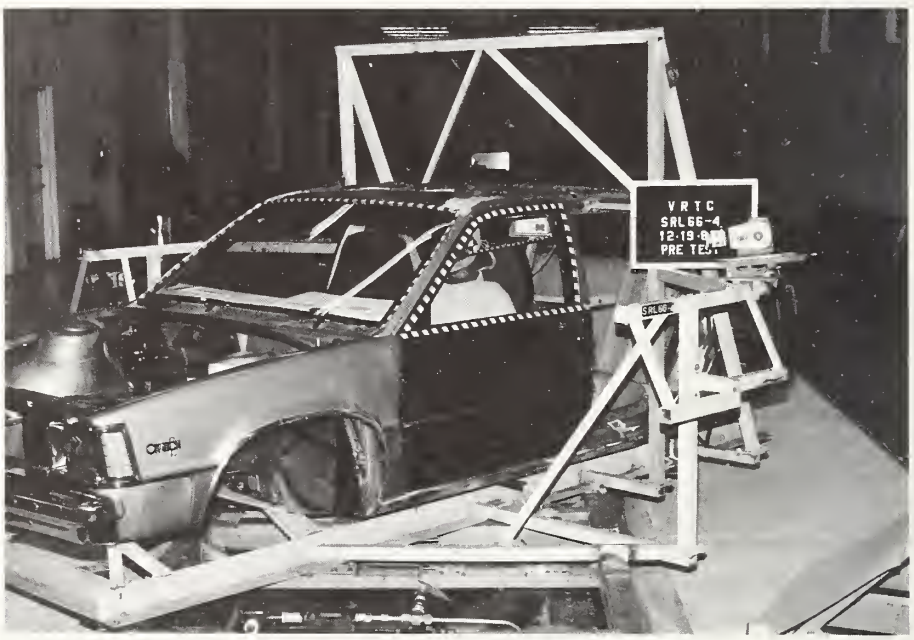


Figure 9.1 Citation Sled Buck

In the first test, a 20 mph test, the buck rocked from side to side excessively. In addition, the dummy seating position resulted in the dummy's head striking the side roof rail first, and then sliding along it into the juncture of the roof rail and the A-pillar. A HIC of 917 and a peak resultant head acceleration of 166g resulted.

The major observation from this test was that the dummy's head showed no noticeable movement as the buck accelerated out from under the dummy, up to the time of impact with the roof rail. This was true despite the contact of its knees with the dashboard and of its chest and pelvis with the interior door.

Two modifications were made to the buck prior to the second test. First of all, foam was removed from the seat in order to lower the dummy's seating height. Second, a few supports were added to the buck to help in stabilizing it. This test, also a 20 mph test, resulted in impact on the A-pillar a little over an inch below the roof rail (double thickness sheet metal at this location). This was satisfactory, although the buck once again rocked excessively. A HIC of 1679 and a peak resultant head acceleration of 229g were the outcome.

The third test was a repeat of the second except it was performed on the left side of the buck. Further supports were added to the buck to help with the stabilization problem. Again, the head struck the A-pillar on the overlap joint but this time the buck was much more stable. This resulted in higher responses with a HIC of 2384 and a peak resultant head acceleration of 304g.

The last Citation test was also performed on the left side of the buck but it used an impact speed of 15 mph. Due to the longer time between initial buck movement and impact for this slower test, the dummy's head rose about 1/2 inch just before contact with the A-pillar. The impact location was judged satisfactory and a HIC of 799 and a peak resultant head acceleration of 191g were the result.

The Rabbit sled buck was built specifically for this set of tests and it was mounted at an angle of 22 degrees to the direction of movement (see figure 9.2). In its normal seated position, the dummy's head was about 15 inches from the A-pillar. This meant, that for the 20 mph tests, the buck was to be accelerated to this speed in under 15 inches, resulting in an acceleration of about 20g. These factors combined to make

Figure 9.2 Rabbit Sled Buck

the stabilization of the buck a much less serious problem than it was with the Citation sled tests.

The first Rabbit buck test, test number 5, was a 20 mph impact into the right side A-pillar. The buck only rocked an amount comparable to the last two Citation tests. The dummy's head first made contact with the side roof rail and then slid along it to the roof rail/A-pillar juncture. The reason for hitting higher than anticipated was that the dummy's head rose about 1 1/2 inches before impact. In addition the dummy's head moved forward about 1 inch before impact. This test resulted in a HIC of 624 had a peak resultant head acceleration of 116g.

There were several possible explanations for the movement of the dummy before impact. One was that as the seat of the vehicle was accelerated out from beneath the dummy, the dummy followed the contour of the seat frame. Since Rabbits have bucket seats, the seat frame provided a bit of an upward ramp. The Citation seats, by contrast, were bench type.

Another possible explanation dealt with the longer distance to impact as compared with the Citation. This gave the head of the dummy more time to react to inputs from other body areas. Examples of these inputs would be chest or pelvis to door contact and knees to dash contact.

Since the distance to impact could not realistically be altered, modifications were made to the seat to lower the dummy's seated position. The seat frame was changed to eliminate the ramp effect and some of the foam cushion was removed. In the second test, test 6, the dummy's head still rose and moved forward about 1 inch, but since the initial seated position was low, it hit the pillar solidly at the desired location. A HIC of 1019 and a peak resultant head acceleration of 180g were the result.

Test number 7 was a repeat of test 6, except that the left side A-pillar was impacted. The dummy's head rose about 1 inch and moved forward about 1/2 inch, contacting the A-pillar at the desired location. It also grazed the wing window support very slightly, but since this occurrence did not appear on the head acceleration traces, it was judged to be inconsequential. This test produced a HIC of 1076 and a peak resultant head acceleration of 157g. These results were very similar to those of the previous test.

The fourth Rabbit buck test, test 8, again impacted the left side pillar, but a speed of 15 mph was used. The dummy's head rose and moved forward about 1 inch, contacting the A-pillar at the desired location. Once again it grazed the wing window support and although it did not appear in the acceleration traces, the high speed films showed that the top of the door frame flexed outward considerably due to this. The calculated HIC was 448 and the peak resultant head acceleration was 93g.

The fifth test, test 9, was a repeat of test 8. This time, the wing window was removed. Once again, the dummy's head hit the A-pillar solidly at the desired location. The grazing of the window support in the previous test must not have had much effect on the response since this test produced a HIC of 415 and a peak resultant acceleration of 95g. These results were very similar to those of test 8.

9.3 Observations

A comparison was made between the results of the sled tests and those of the corresponding head component tests. The stiffnesses found from the rigid headform component tests on the upper A-pillars of the Citation and Rabbit were used to predict a value for HIC in each case. These values were used in the comparison with the sled test results.

Tests 1 and 2 (Citation buck) were not used due to the problems mentioned in the previous section. Test 3, therefore, provided the 20 mph Citation results, while test 4 provided the 15 mph Citation results. Test 5 (Rabbit buck) was also not used due to the problems stated earlier. The average of tests 6 and 7 was used for the 20 mph Rabbit results, while the average of tests 8 and 9 was used for the 15 mph Rabbit results (see table 9.3).

Table 9.3
HYGE SLED AND COMPONENT TEST RESULTS

VEHICLE	HIC		
	HYGE SLED		COMPONENT
	15 mph	20 mph	15 mph
CITATION	799	2384	2248
RABBIT	432	1048	1877

Since the number of tests was so small, a valid transfer function that correlates the HIC values of the sled tests to those of the component tests was not found. Several observations were made though. One of these was that the Citation produced HIC values that were clearly higher than those of the Rabbit, regardless of the impact speed or the type of testing used. One possible explanation for this was that the A-pillar section impacted on the Citation was a joint with overlapping sheet metal.

Table 9.3 also shows that, given the same impact speed, component testing produced a more severe impact than the sled tests. This was expected since the component test hardware only allowed an interior impact angle of about 90 degrees (i.e. perpendicular to the A-pillar), while the sled tests result in more realistic glancing angles.

Finally, it appeared that the 15 mph component tests (with direct impacts) were roughly comparable to the 20 mph sled tests. Although a clear relationship between the two types of testing was not evident, the magnitudes of the HIC values for these sets of tests were comparable. This was especially true in the case of the Citation.

10.0 EFFECT OF HOOD HEIGHT ON DOOR AREA STIFFNESS

There are several factors that possibly contribute to the level of injury to the victim of a side impact collision. Some of these include the velocity of the collision, the angle of impact, the side structural characteristics of the struck vehicle, the amount of energy absorption materials involved, and the structural characteristics of the front end of the striking vehicle. Previous investigations done as part of this project have measured the side structural characteristics of several vehicles and correlated these to the resulting injury levels. This was done by testing the different vehicles while holding impact velocity, angle, and striking vehicle front end characteristics constant.

A preliminary study was then done to examine the effect of varying the front end characteristics of the striking vehicle, in particular, lowering of the hood profile. All these tests were done using early model (1976-77) Volkswagen Rabbits. Likewise, impact velocity and angle were held constant.

10.1 Approach

The procedure used to perform this set of tests was very similar to that utilized in conducting the SID thorax, crushed door component tests reported in section 5.1 of this report. The only difference was in the orientation of the aluminum honeycomb used to simulate the front end of the striking vehicle.

A horizontal reference line (0") on the door was defined at the vertical location that the upper edge of the SID thorax ribcage would contact in the component testing. The reference line was 1/2 inch below the window level, resulting in an impact area that was judged to be representative of the area on the door that an occupant's thorax would contact in a side collision. It will be shown that the SID, seated in the vehicle, has the ribcage inclined at the seat back angle and reaching into the window opening. This approach was simplified in that the ribs were horizontal and therefore did not extend into the window opening.

These tests examined the response change that resulted from lowering the honeycomb level on the door, thus estimating the effect of lowered hood height. Six levels were tested which were from the reference line to ten inches below this line, inclusive, using two inch increments. A full-sized section of honeycomb (18" x 18" x 5") was used until its lower edge reached the rocker panel. For these tests, the lower edge of the honeycomb was cut off such that it just overrode the rocker panel. The main reason for this was that bumper heights are such that they generally override the rocker panel in a side impact. Since bumper height could be a separate variable, it was held constant in these tests. Figure 10.1 is a photograph of the exterior crush of one of these tests.

10.2 Results

Table 10.1 lists the average rib acceleration for each honeycomb height as well as those for the upper and lower ribs separately. Figure 10.2 is a plot of rib response against honeycomb location. The spinal results of these tests are not included. The

Figure 10.1 Exterior Crush

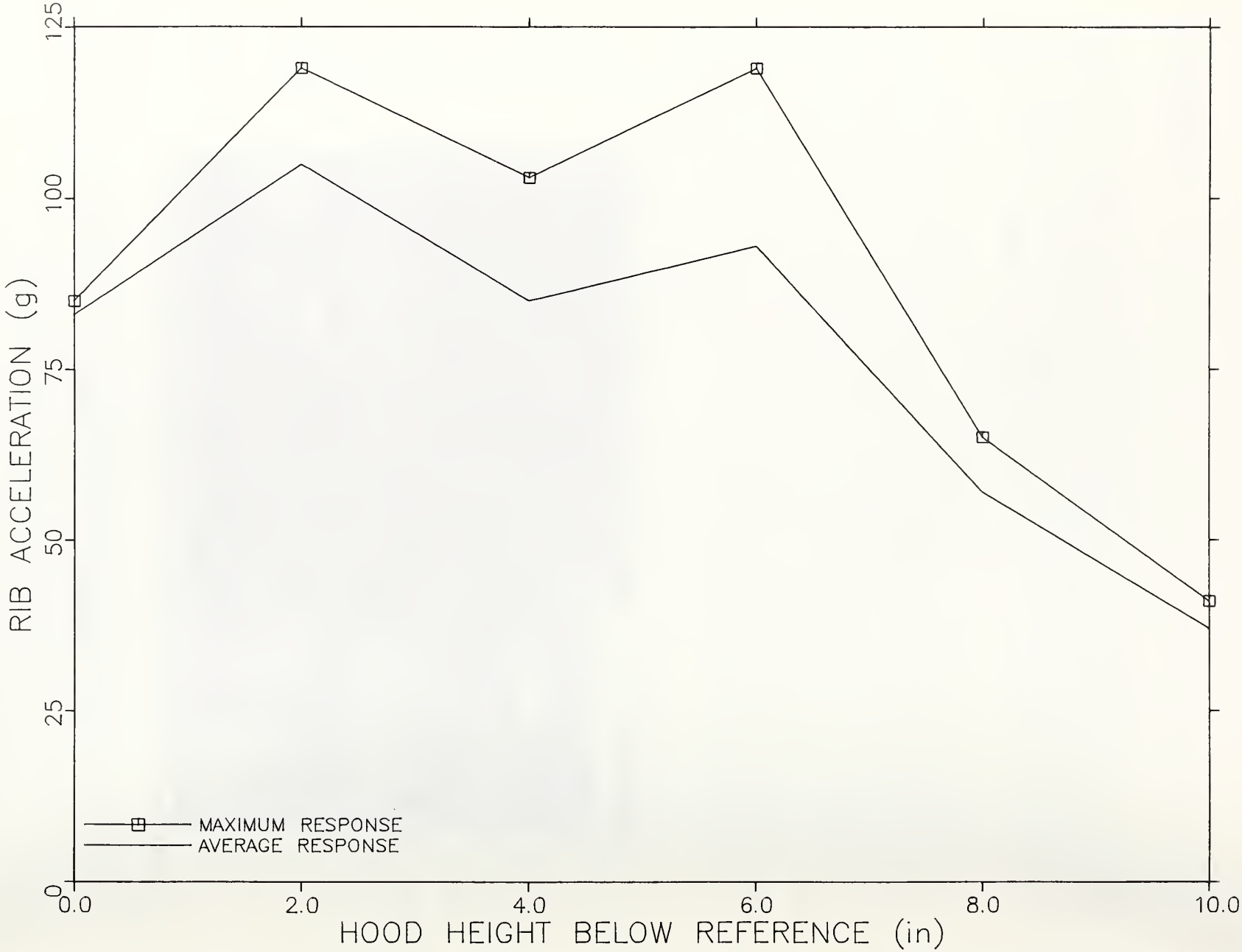


FIGURE 10.2. RIB RESPONSE VS HOOD HEIGHT

reason for this is that for the tests done with crushing 8" and 10" below the reference line, the upper door contacted the crushing plate as the door deflected outward. This contact occurred late enough in the event so as to not affect the rib responses, but the spinal responses were contaminated. Since this was just a preliminary investigation, these tests were not repeated.

Table 10.1
HOOD HEIGHT COMPONENT TEST RESULTS

HONEYCOMB LOCATION- distance below reference line	RIB ACCELERATION (g)		
	UPPER	LOWER	AVERAGE
0"	85	82	83
2"	91	119	105
4"	67	103	85
6"	68	119	93
8"	65	50	57
10"	32	41	37

10.3 Observations

The results of the 0", 2", 4", and 6" level tests fluctuated considerably and therefore indicated no patterned increase or decrease in rib response (see figure 10.2). The 8" and 10" test results, on the other hand, showed a sharp reduction in the peak rib accelerations. A possible explanation for this was that the ribcage of the SID thorax (including the rib cover but not the jacket) was about six inches high. This meant that some part of the ribcage impact area was backed by honeycomb in each of the first four test levels. Once the honeycomb was lowered below this level, the ribcage no longer contacted a directly backed surface, thus the lower responses for the 8" and 10" test levels.

Another observation dealt with the relationship between the upper and lower rib responses. As table 10.1 shows, there was very little difference between the upper and lower rib responses for the 0" test level. This could be expected since the honeycomb backs the impact area behind both rib locations equally.

A different trend was observed for the 2", 4", and 6" test levels. In each of these, the lower rib acceleration was higher than that of the upper ribs. In addition, the percentage difference increased with the lowering of the honeycomb level. Again, this was not unexpected since in each of these tests, the honeycomb did not directly back the door at the upper rib location but it did at the lower rib location. As the level lowered, more of the load was carried by the lower ribs.

No such trend was seen in the results of the 8" and 10" level tests. The first of these showed a higher upper rib response while the second showed the reverse. In each case, though, the percentage difference was lower than it had been for the two previous test levels.

10.4 Preliminary survey of front end profiles

A future study will include a series of side impact crash tests that simulate a lowered hood profile on the striking vehicle. The component test results mentioned previously indicated that a reduction of struck vehicle occupant response should occur if the hood is sufficiently lowered. The reduction in hood height possible in actual

vehicles is probably limited by such factors as engine size, location, and orientation as well as occupant compartment configuration, etc. The following preliminary survey was done in an attempt to gain some insight as to the types of front end designs that are currently being produced.

A 1976 Volkswagen Rabbit was used as the standard "struck" car. A SID dummy was placed in the driver seat and sandbags were distributed throughout the car. These sandbags were used to achieve a weight distribution similar to that of previously crash tested Rabbits. The heights at various locations on the vehicle and dummy were recorded (see table 10.2). Figure 10.3 shows the seating position of the dummy relative to both the ground and the vehicle. The shaded area on the door indicates the location of the dummy's ribcage. For reasons mentioned previously, the location of the SID ribcage relative to the door in this figure does not duplicate that of the thoracic component tests.

A sample of twenty vehicles which were available at the VRTC was used in this survey. Hood and bumper dimensions were recorded for each of these (see tables 10.3 and 10.4). Since the measured values were generally not sufficient to describe the front end profiles, a photograph of each front end was taken. In addition, the driver side door of the Rabbit was removed and photographs were taken which showed the front end of the survey vehicles relative to the dummy seated position in the car (see Appendix F). Since the twenty cars used in this study were chosen according to availability, it was not intended that they be used as a representative cross-section of all cars sold. Therefore, the averages listed in tables 10.3 and 10.4 pertain only to the surveyed vehicles.

The component tests for this segment of the project demonstrated a possibility for reduced thoracic injury if the front end profile of the striking vehicle were lowered to a height below that of the thorax. In the case of a VW Rabbit as the struck vehicle, a hood height of less than 28" would be desirable. This survey showed that some vehicles are currently produced with such front end profiles, while several others would require only a small amount of modification.

Further investigation of the effect of hood height on occupant safety will be done as part of project SRL-92, "Side Impact Aggressiveness Attributes". In this study,

Figure 10.3 Dummy Seating Position

several crash tests will be performed on VW Rabbits using the NHTSA's MDB as the striking vehicle. Some of the honeycomb barrier fronts used in these tests will have a forward edge that has been lowered from 33" to 25" off of the ground. This should contact the door well below the dummy's thorax and give a realistic indication of the effect of lowered hood profile.

Table 10.2

HEIGHTS FROM GROUND - LOADED RABBIT

VEHICLE	
Attitudes	
RF - 24.3"	RR - 23.1"
LF - 23.3"	LR - 22.6"
Top of Sill	
front - 10.8"	
rear - 10.6"	
Door Window Ledge	
front - 34.0"	
rear - 33.8"	
DUMMY	
Hip Point - 18.8"	Ribcage
	upper - 35.2"
Head CG - 44.3"	lower - 27.7"

Table 10.3
HOOD PROFILES

VEHICLES	HOOD HEIGHT* (inches)	DISTANCE FROM FRONT OF BUMPER* (inches)
Datsun 280 Z	22.7 (29.5)	6.3 (19.3)
Isuzu Impulse	25.9	5.5
Honda Prelude	25.9	6.5
Toyota Camry	28.6	5.4
Plymouth Turismo	28.8	10.0
Mitsubishi Starion	28.9	10.1
Nissan Sentra	29.4	8.0
Toyota Celica	29.4	10.0
Chevrolet Cavalier	29.8	6.5
Plymouth Horizon	30.1	7.0
Mercury Lynx	30.4	6.8
Dodge 600	30.6	6.8
Chevrolet Chevette	30.9	6.6
Buick Skylark	31.0	5.0
Ford Thunderbird	31.4	7.8
Datsun 810 Wagon	31.6	4.0
AMC Spirit	31.9	7.8
Ford LTD Wagon	32.4 (34.6)	4.5 (9.0)
Volvo GL	33.2	5.0
Ford Bronco	39.6 (42.5)	2.3 (5.8)
AVERAGE	30.1	6.6
Current MDB	33.0	4.0

* Measurements taken at major bend in front end of vehicle

( ) Measurements taken at second bend, if present

Table 10.4
BUMPER PROFILES

VEHICLES	BUMPER HEIGHT (inches)		
	TOP	BOTTOM	WIDTH
Datsun 280 Z	18.6	15.0	3.6
Isuzu Impulse	19.8	14.9	4.9
Honda Prelude	20.4	16.1	4.3
Toyota Camry	21.0	15.6	5.4
Plymouth Turismo	21.5	12.9	8.6
Mitsubishi Starion	21.4	14.3	7.1
Nissan Sentra	21.0	14.1	6.9
Toyota Celica	21.7	14.4	7.3
Chevrolet Cavalier	20.4	14.8	5.6
Plymouth Horizon	19.9	15.2	4.7
Mercury Lynx	20.6	15.3	5.3
Dodge 600	20.9	13.0	7.9
Chevrolet Chevette	19.8	13.8	6.0
Buick Skylark	19.5	14.5	5.0
Ford Thunderbird	21.5	13.9	7.6
Datsun 810 Wagon	19.5	14.4	5.1
AMC Spirit	20.1	13.6	6.5
Ford LTD Wagon	21.4	13.4	8.0
Volvo GL	19.9	14.4	5.5
Ford Bronco	24.6	18.5	6.1
AVERAGE	20.7	14.6	6.1
Current MDB	21.0	13.0	8.0

11.0 CONCLUSIONS AND RECOMMENDATIONS

From this study, the following was concluded:

* From the seven vehicles tested for door area stiffness, there was a large range of stiffnesses in both the crushed and the unbacked door modes.

  - Crushed door stiffnesses ranged from 668 to 1891 lb/in.

  - Unbacked door stiffnesses ranged from 299 to 1070 lb/in.

* From the seven vehicles tested for upper interior stiffness, there was a large variation in stiffnesses, both between similar structures of different vehicles, and between different structures of the same vehicle.

  - Upper A-pillar stiffnesses ranged from 1092 to 2792 lb/in. (Impact locations were 2-3 in. below the roof rails.) The average was 1971 lb/in.

  - Lower A-pillar stiffnesses ranged from 1039 to 2203 lb/in. (Impact locations were approximately mid-way between roofs rails and cowls.) The average was 1520 lb/in.

  - Side roof rail stiffnesses ranged from 588 to 1607 lb/in. The average was 1050 lb/in.

  - Front roof rail stiffnesses ranged from 356 to 1015 lb/in. The average was 751 lb/in.

  - The two B-pillar stiffnesses were 1022 and 1036 lb/in.

* From the small number of tests performed, it appeared that 20 mph impact responses obtained from the SID thorax could be predicted from the results of a less complex rigid thorax test, when each was used as a component test surrogate chest. The average rib, maximum rib, and average spinal SID thorax responses were predicted for the crushed door tests using the following models:

$$XRA = 0.0620\,(F15) - 0.812\,(DRWT) - 0.1017\,(PCS) + 121.4 \qquad r^2 = .96$$

Sensitivities: F15 - 37% DRWT - 23% PCS - 40%

$$XRM = 0.0621\,(F15) - 1.007\,(DRWT) - 0.1241\,(PCS) + 161.1 \qquad r^2 = .95$$

Sensitivities: F15 - 32% DRWT - 25% PCS - 43%

$$XSA = 0.0497\,(SP) - 0.0108\,(F25) - 0.161\,(DRWT) + 52.8 \qquad r^2 = .98$$

Sensitivities: SP - 58% F25 - 37% DRWT - 5%

Where XRA, XRM, and XSA are the predicted average rib, maximum rib, and average spinal accelerations, respectively. F15 and F25 are the measured dynamic forces at 1.5" and 2.5" of deflection. SP is the stiffness up to peak force found from the dynamic tests while PCS is the static crush stiffness up to peak force.

These same responses were predicted for the unbacked door tests using the following models:

$$XRA = 0.0259\,(F15) + 0.980\,(DRWT) - 22.1 \qquad r^2 = 1.00$$

Sensitivities: F15 - 58% DRWT - 42%

$$XRM = 0.0284\,(F15) + 1.029\,(DRWT) - 23.5 \qquad r^2 = 1.00$$

Sensitivities: F15 - 59% DRWT - 41%

$$XSA = 0.0109\,(F25) - 0.0088\,(F30) + 37.3 \qquad r^2 = 0.96$$

Sensitivities: F25 - 55% F30 - 45%

Where F30 is the measured dynamic force at 3.0" of deflection.

* Rib and spinal responses were found to be highly sensitive to variations in door parameters (stiffness and weight). This is shown by the sensitivities associated with the above models. The sensitivity to a given door parameter is defined as the percent change in the rib or spine response that would result from varying the parameter over the full range of variation observed in the tests.

* This study indicated a potential for developing a relationship between door and/or vehicle characteristics that can be measured in a component test environment, and SID dummy responses measured in a crash test environment. At this point, too few tests have been done to determine this relationship with confidence.

* For the procedures and hardware used in this study, there was a strong relationship between the measured stiffness of an interior structure and the HIC resulting from a 15 mph impact with that structure. The relationship is as follows:

$$HIC = 0.927\,(STIFFNESS) + 35.2 \qquad r^2 = 0.90$$

* The head component tests performed in this study produced more severe impacts than full dummy HYGE sled tests of the same velocity.

  - The component tests did not allow glancing impact as did the full dummy tests.

  - The 15 mph component tests produced HIC values that were of the same magnitude as the 20 mph full dummy tests.

  - Too few tests were done to develop a valid transfer function between the two types of tests.

* Based upon the rib responses of the thoracic component tests done in this study, it may be possible to reduce thoracic injury in side impacts if the engaging surface of the striking vehicle is kept below the occupant's thoracic region.

  - When the hood height simulated in thoracic component tests was within the vertical level of the thoracic region (28" to 35" from ground level), the average rib responses fluctuated from 83g to 105g. These dropped to 57g and 37g as the height fell 2" and then 4" below this region (26" then 24" from ground level). The vehicles sampled at the VRTC had an average hood height of 30", ranging from 23" to 40".

Based on the above results, it is recommended that more testing be done in order to enlarge the number of samples to be used in the development of models that would predict the results of the complex thorax and head tests using the results of the much simpler tests. In addition, further investigation should be made of striking vehicle attributes, such as that to be done as part of SRL-92.

REFERENCES

(1). "Development of a Promising Universal Thoracic Trauma Prediction Methodology", R.H. Eppinger, K. Augustyn, D.H. Robbins; Twenty-Second Stapp Car Crash Conference, Paper Number 780891; October 1978.

(2). "Development of Dummy and Injury Index for NHTSA's Thoracic Side Impact Protection Research Program", R.H. Eppinger, J.H. Marcus, R.M. Morgan; SAE Technical Paper no. 840885· May 1984.

APPENDIX A

Door Area Test Results

Seven vehicles were initially used in the door area stiffness measurement tests. These were a VW Rabbit, a 2-door Honda Civic, a Pontiac Phoenix, a Ford Mustang, a Chevrolet Malibu, a Ford Granada, and a Plymouth Horizon. This section contains tables of the results of these tests, along with their test numbers. A force vs. deflection curve is also included for each test performed with the rigid thorax.

A list of the variables attempted in the SAS analysis is included along with their abbreviations. This section also contains the values of these variables for the various vehicles and tests.

The results of the padded VW Rabbit and the 4-door Honda Civic are listed here. This includes SAS variable values, peak accelerations, and a force vs. deflection curve for each vehicle.

Finally, this section contains photographs which depict various stages of the door area tests done on the VW Rabbit.

VEHICLE			RABBIT		CIVIC	
DOOR CONDITION			UNBACKED	CRUSHED	UNBACKED	CRUSHED
TEST NUMBER			26	27	71	72
PEAK ACCELERATION	RIBS	UPPER	49.9	72.6	36.2	89.4
		LOWER	56.0	107.0	49.6	115.4
		AVERAGE	52.9	89.8	42.9	102.4
	SPINE	UPPER	42.0	90.4	43.1	88.4
		LOWER	38.8	89.5	38.6	87.0
		AVERAGE	40.4	89.9	40.8	87.7
TEST NUMBER			23	25	69	70
STIFFNESS (lb/in)			551	1789	299	1488

VEHICLE			PHOENIX		MUSTANG	
DOOR CONDITION			UNBACKED	CRUSHED	UNBACKED	CRUSHED
TEST NUMBER			30	31	67	68
PEAK ACCELERATION	RIBS	UPPER	74.6	100.9	43.8	87.4
		LOWER	82.9	120.5	43.3	74.8
		AVERAGE	78.7	110.7	43.6	81.1
	SPINE	UPPER	38.3	84.1	37.6	83.4
		LOWER	37.6	81.9	35.5	85.1
		AVERAGE	37.9	83.0	36.6	84.3
TEST NUMBER			28	29	65	66
STIFFNESS (lb/in)			522	1572	357	1891

VEHICLE			MALIBU		GRANADA	HORIZON
DOOR CONDITION			UNBACKED	CRUSHED	CRUSHED	CRUSHED
TEST NUMBER			54	55	113	126
PEAK ACCELERATION	RIBS	UPPER	101.5	127.9	102.4	56.7
		LOWER	84.0	116.7	76.5	58.6
		AVERAGE	92.7	122.3	89.4	57.6
	SPINE	UPPER	46.1	86.1	87.4	57.4
		LOWER	41.1	82.0	86.8	55.9
		AVERAGE	43.6	84.1	87.1	56.6
TEST NUMBER			51	52	112	114
STIFFNESS (lb/in)			1070	1718	1306	668

HONEYCOMB ONLY:

Test Number - 64 Stiffness - 2440 lb/in

ABBREVIATIONS FOR INDEPENDENT VARIABLES

S15 - stiffness at 1.5" of deflection (lb/in)
S20 - stiffness at 2.0" of deflection (lb/in)
S25 - stiffness at 2.5" of deflection (lb/in)
S30 - stiffness at 3.0" of deflection (lb/in)
SP - stiffness up to peak force (lb/in)
F15 - force at 1.5" of deflection (lb)
F20 - force at 2.0" of deflection (lb)
F25 - force at 2.5" of deflection (lb)
F30 - force at 3.0" of delfection (lb)
FP - peak force (lb)
VW - vehicle curb weight (lb)
DRWT - door weight - no glass (lb)
DTM - maximum door thickness (in)
DT3 - door thickness 3" below window opening (in)
PCS - stiffness to peak force from exterior door crush (lb/in)
PCF - peak force from exterior door crush (lb)

ABBREVIATIONS FOR DEPENDENT VARIABLES

RIBA - average rib acceleration (g)
RIBM - maximum rib acceleration (g)
SPNA - average spinal acceleration (g)
XRSA - average of adjusted average rib acceleration and SPNA (g)
XRSM - average of adjusted maximum rib acceleration and SPNA (g)

INDEPENDENT VARIABLE VALUES

VARIABLE	VEHICLE - CRUSHED DOORS						
	RABBIT	PHOENIX	MALIBU	MUSTANG	CIVIC	GRANADA	HORIZON
S15	918	844	1626	1057	943	1263	908
S20	975	1037	1527	1087	909	1130	828
S25	1098	1164	1519	1325	967	977	741
S30	1390	1295	1597	1624	1165	945	685
SP	1789	1572	1711	1891	1488	1306	668
F15	1605	1942	2147	1600	1381	1789	1402
F20	2078	2633	2854	2500	1742	1606	1277
F25	3999	3651	3881	4977	3200	1910	1412
F30	6220	4877	5618	7320	5115	2981	1762
VW	1865	2517	3089	2635	1761	2801	2230
DRWT	47.4	44.8	76.6	59.5	40.6	61.8	40.6
DTM	4.3	5.5	6.4	4.9	5.0	5.0	5.0
DT3	3.5	4.3	5.3	4.5	4.0	3.8	3.8
PCS	830	930	710	860	770	946	1222
PCF	5800	6700	6100	6700	6100	7500	6400

INDEPENDENT VARIABLE VALUES

VARIABLE	VEHICLE - UNBACKED DOORS				
	RABBIT	PHOENIX	MALIBU	MUSTANG	CIVIC
S15	743	1578	1326	174	833
S20	734	1394	1091	199	757
S25	705	1143	1078	281	680
S30	670	915	1045	382	606
SP	551	522	1070	357	299
F15	1093	2165	1583	257	1058
F20	1386	1969	1905	635	1261
F25	1587	1332	2641	1293	1258
F30	1695	1456	2499	1664	1176
FP	2815	2340	2818	2586	2063
VW	1865	2517	3089	2635	1761
DRWT	47.4	44.8	76.6	59.5	40.6
DTM	4.3	5.5	6.4	4.9	5.0
DT3	3.5	4.3	5.3	4.5	4.0

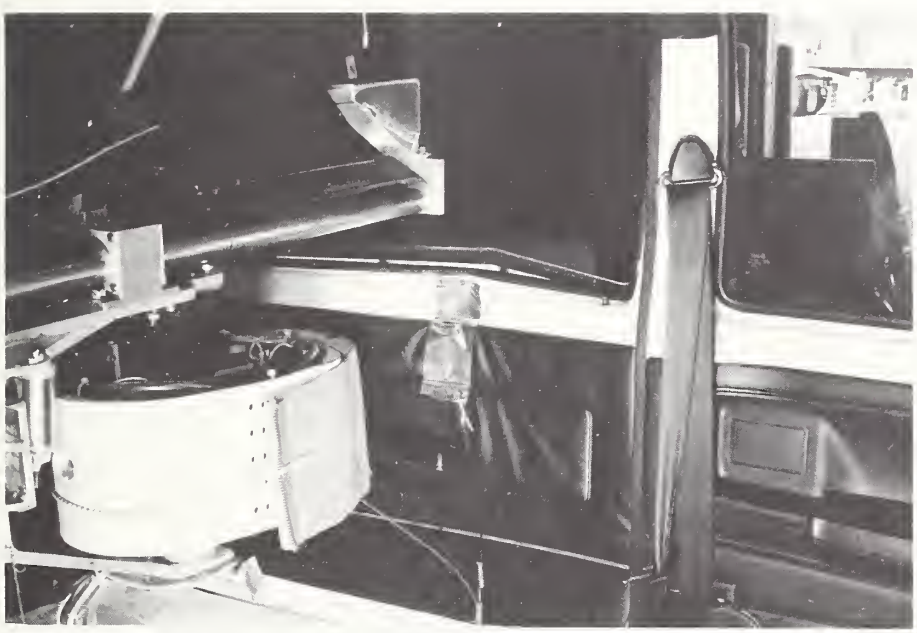
DEPENDENT VARIABLE VALUES

VEHICLE	COMPONENT TESTS						CRASH TESTS	
	CRUSHED			UNBACKED				
	RIBA	RIBM	SPNA	RIBA	RIBM	SPNA	XRSA	XRSM
RABBIT	90	107	90	53	56	40	101	104
PHOENIX	111	120	83	79	83	38	82	83
MALIBU	122	128	84	93	101	44	xxx	xxx
MUSTANG	81	87	84	44	44	37	xxx	xxx
CIVIC	102	115	88	43	50	41	xxx	xxx
GRANADA	89	102	87	xxx	xxx	xxx	87	90
HORIZON	52	54	64	xxx	xxx	xxx	89	92

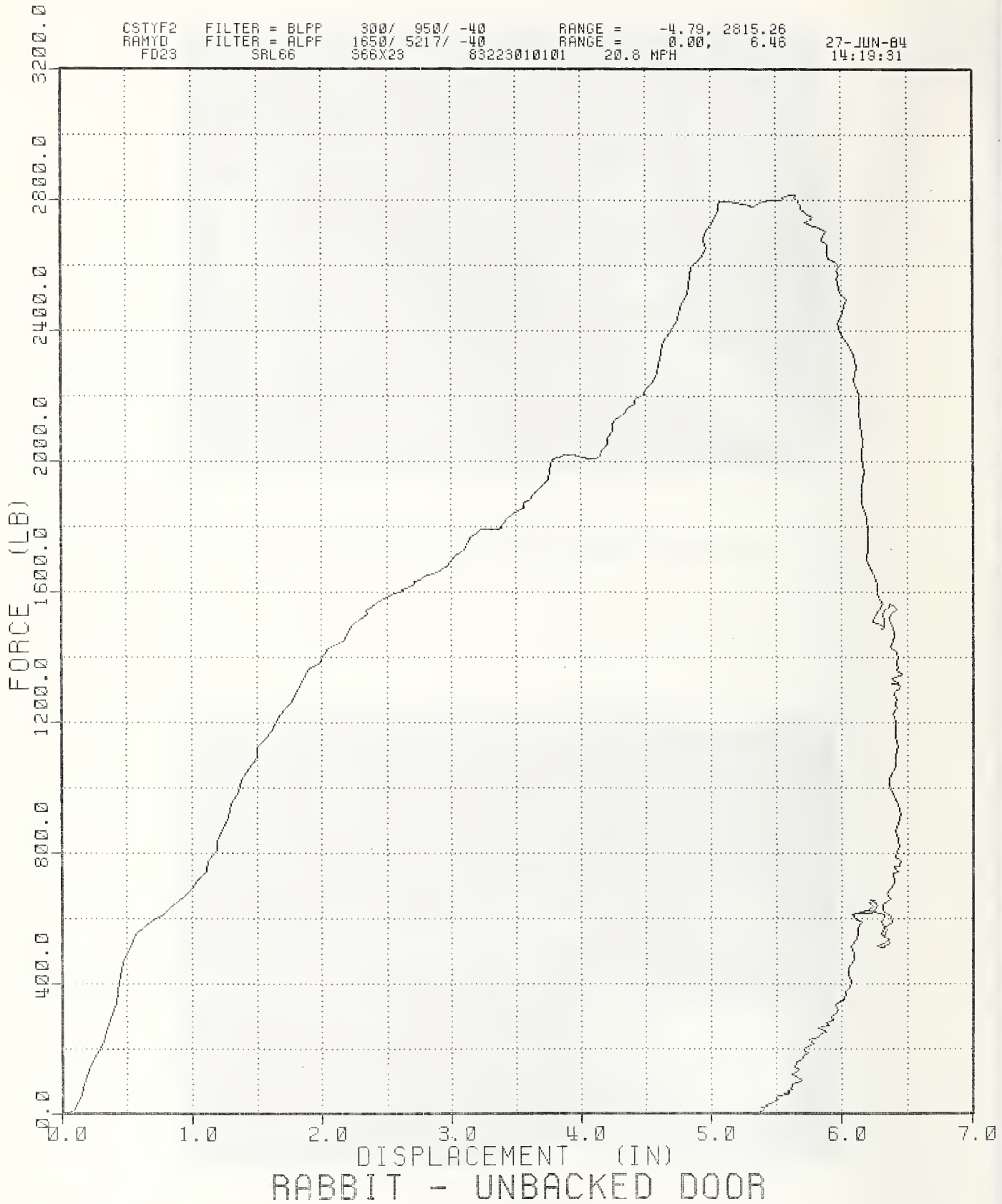
Pre-Test - Rigid Thorax

Exterior Crush

Post-Test - Rigid Thorax - Crushed Door



Post-Test - SID Thorax - Unbacked Door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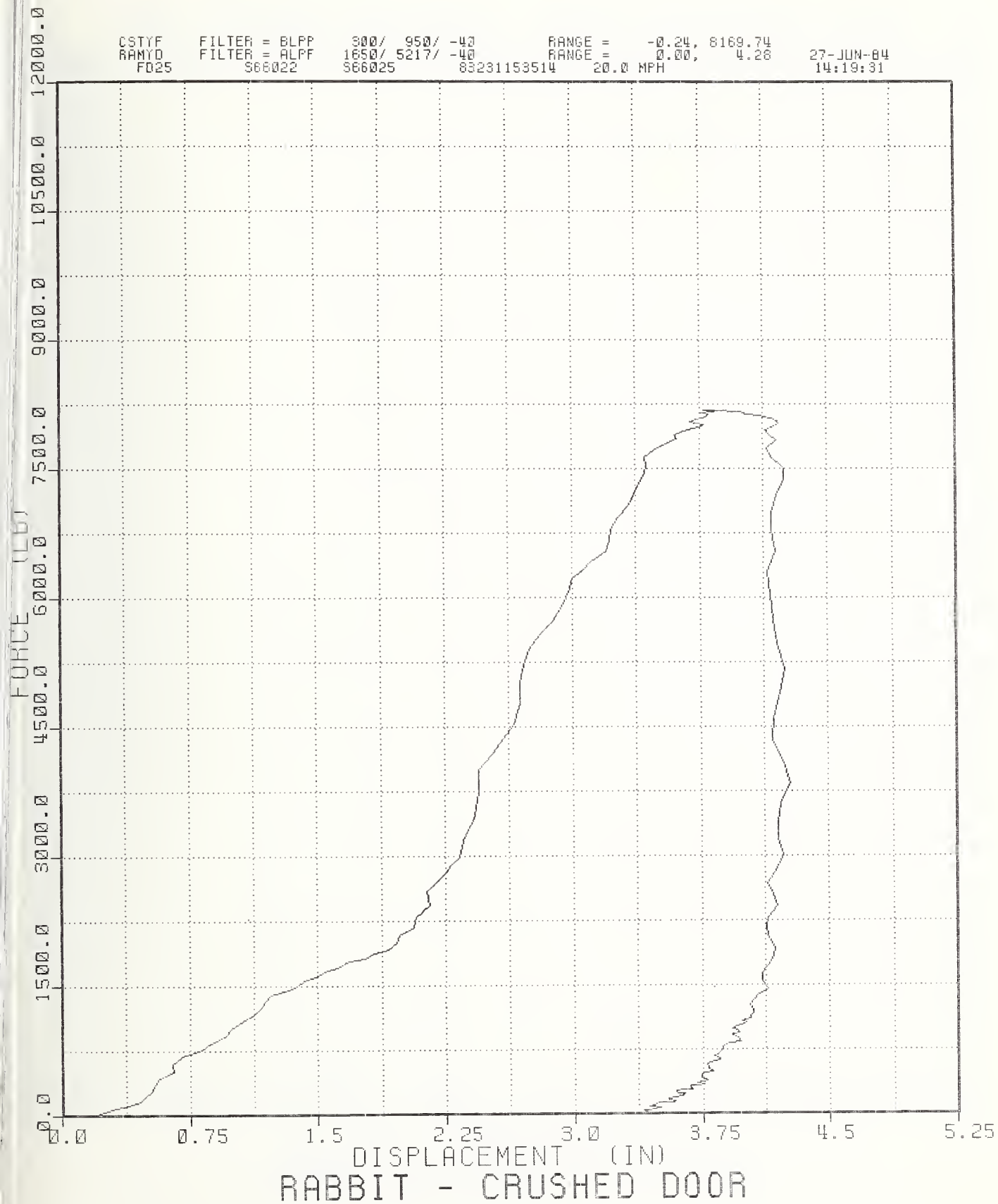
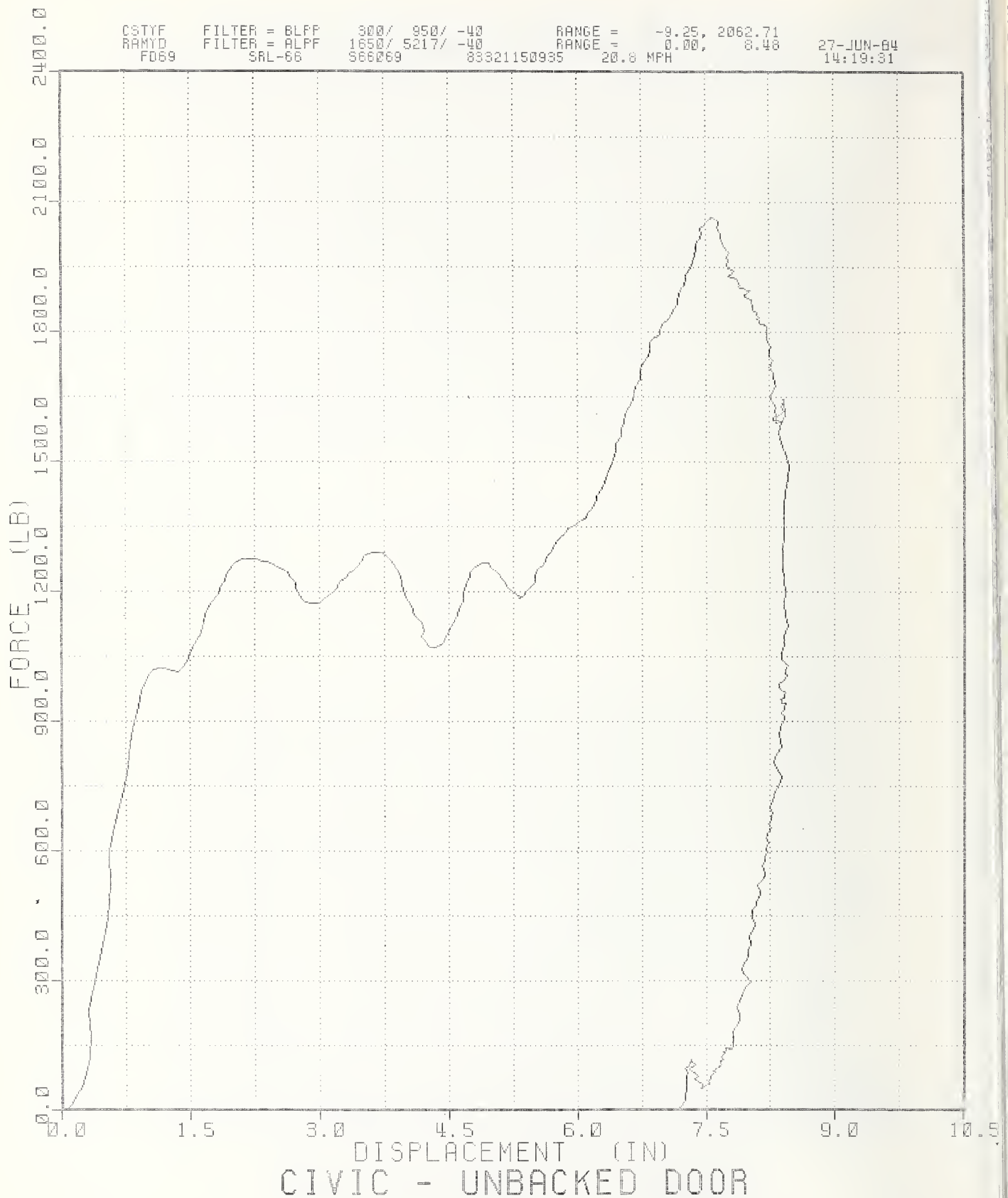
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 6.46 27-JUN-84
FD23 SRL66 S66X23 8322301010I 20.8 MPH 14:19:31
FORCE (LB)
3200.0
2800.0
2400.0
2000.0
1600.0
1200.0
800.0
400.0
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
DISPLACEMENT (IN)
RABBIT - UNBACKED DOOR



RABBIT - CRUSHED DOOR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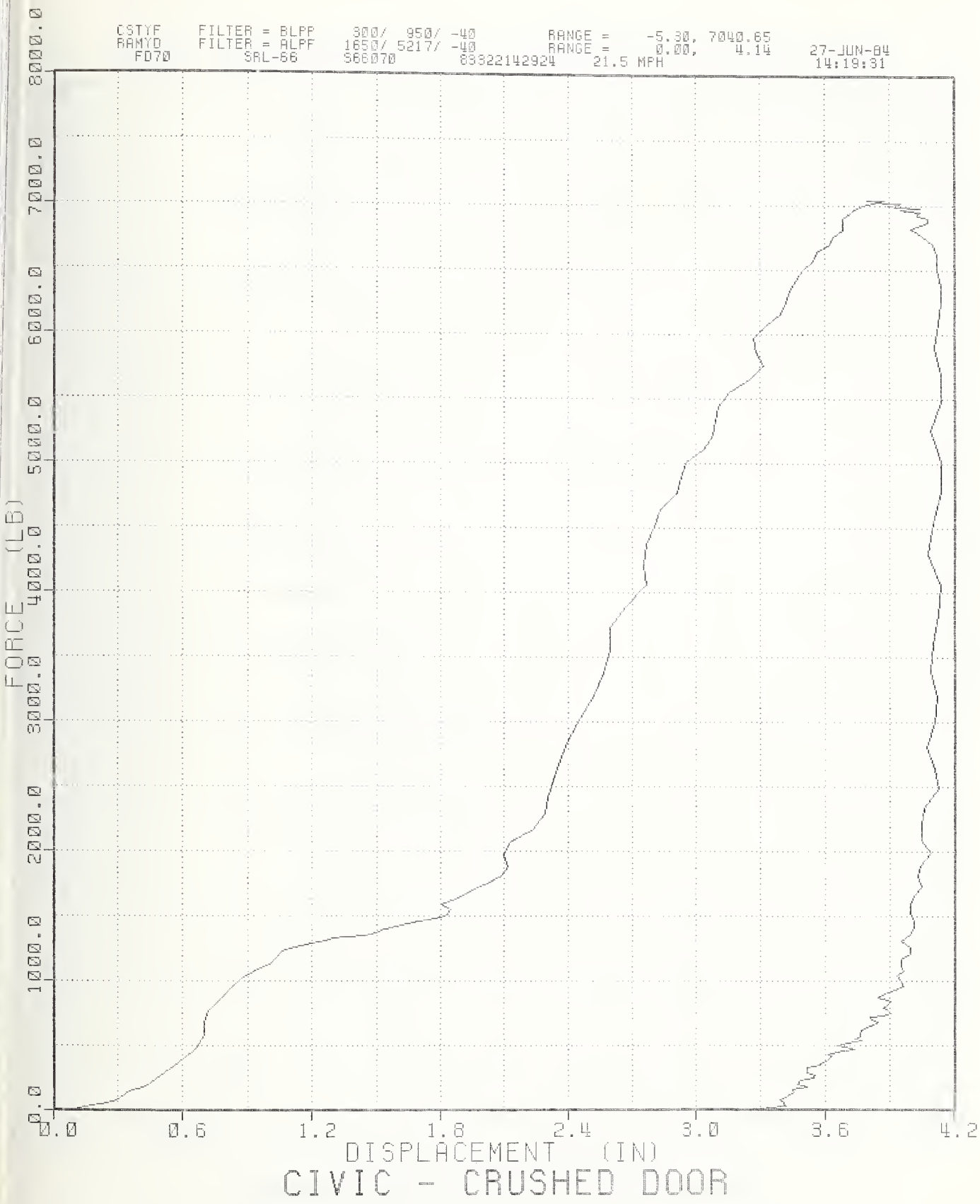
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 8.48 27-JUN-84
FD69 SRL-66 S66069 83321150935 20.8 MPH 14:19:31
FORCE (LB)
2400.0
2100.0
1800.0
1500.0
1200.0
900.0
600.0
300.0
0.0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
DISPLACEMENT (IN)
CIVIC - UNBACKED DOOR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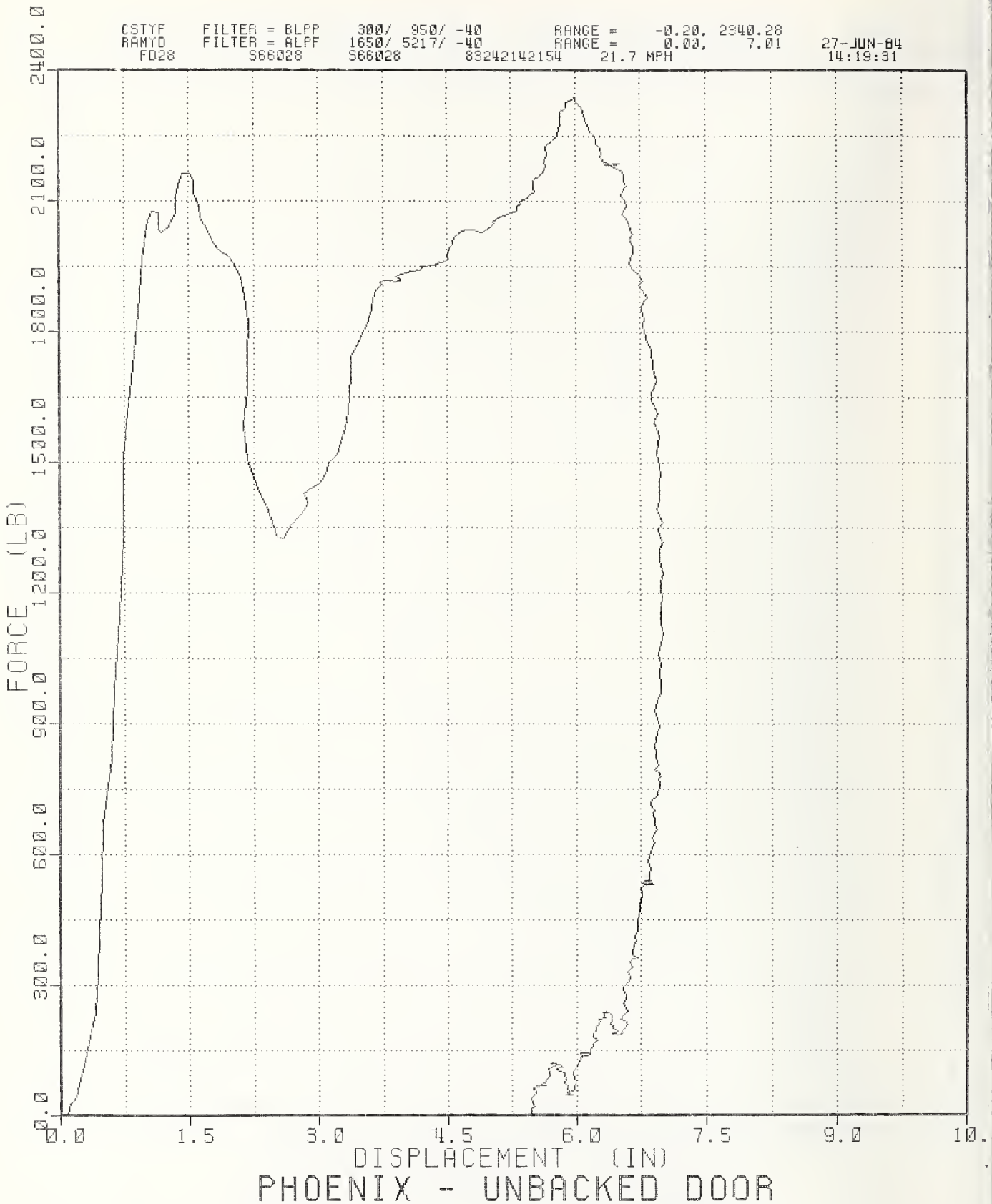
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 4.14 27-JUN-84
FD70 SRL-66 S66070 83822142924 21.5 MPH 14:19:31
FORCE (LB)
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
DISPLACEMENT (IN)
CIVIC - CRUSHED DOOR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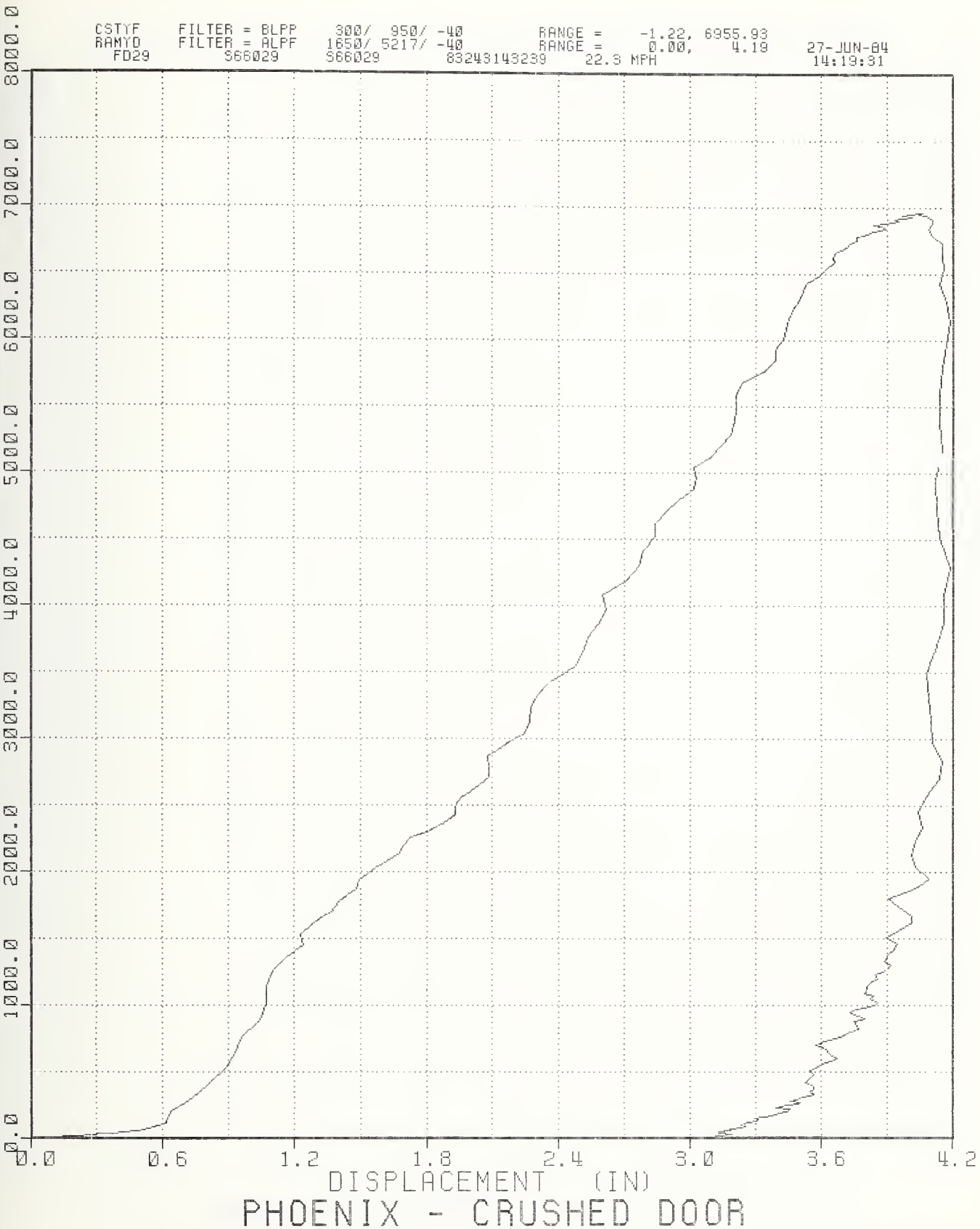
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 7.01
FD28 S66028 S66028 83242142154 21.7 MPH
27-JUN-84
14:19:31
FORCE (LB)
0.0
300.0
600.0
900.0
1200.0
1500.0
1800.0
2100.0
2400.0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.
DISPLACEMENT (IN)
PHOENIX - UNBACKED DOOR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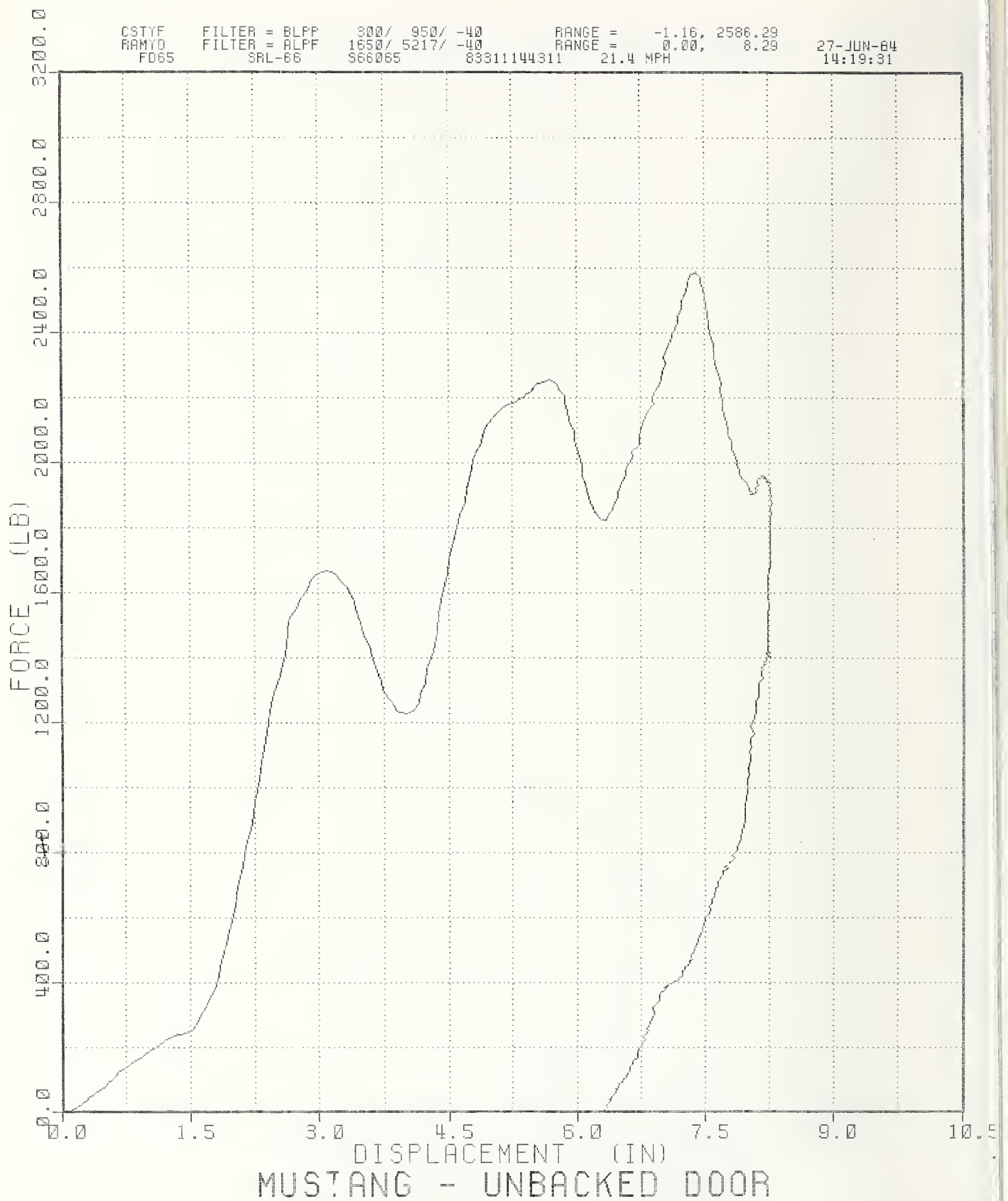
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 4.19
FD29 S66029 S66029 83243143239 22.3 MPH
27-JUN-84
14:19:31
FORCE (LB)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
8000.0
0.0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
DISPLACEMENT (IN)
PHOENIX - CRUSHED DOOR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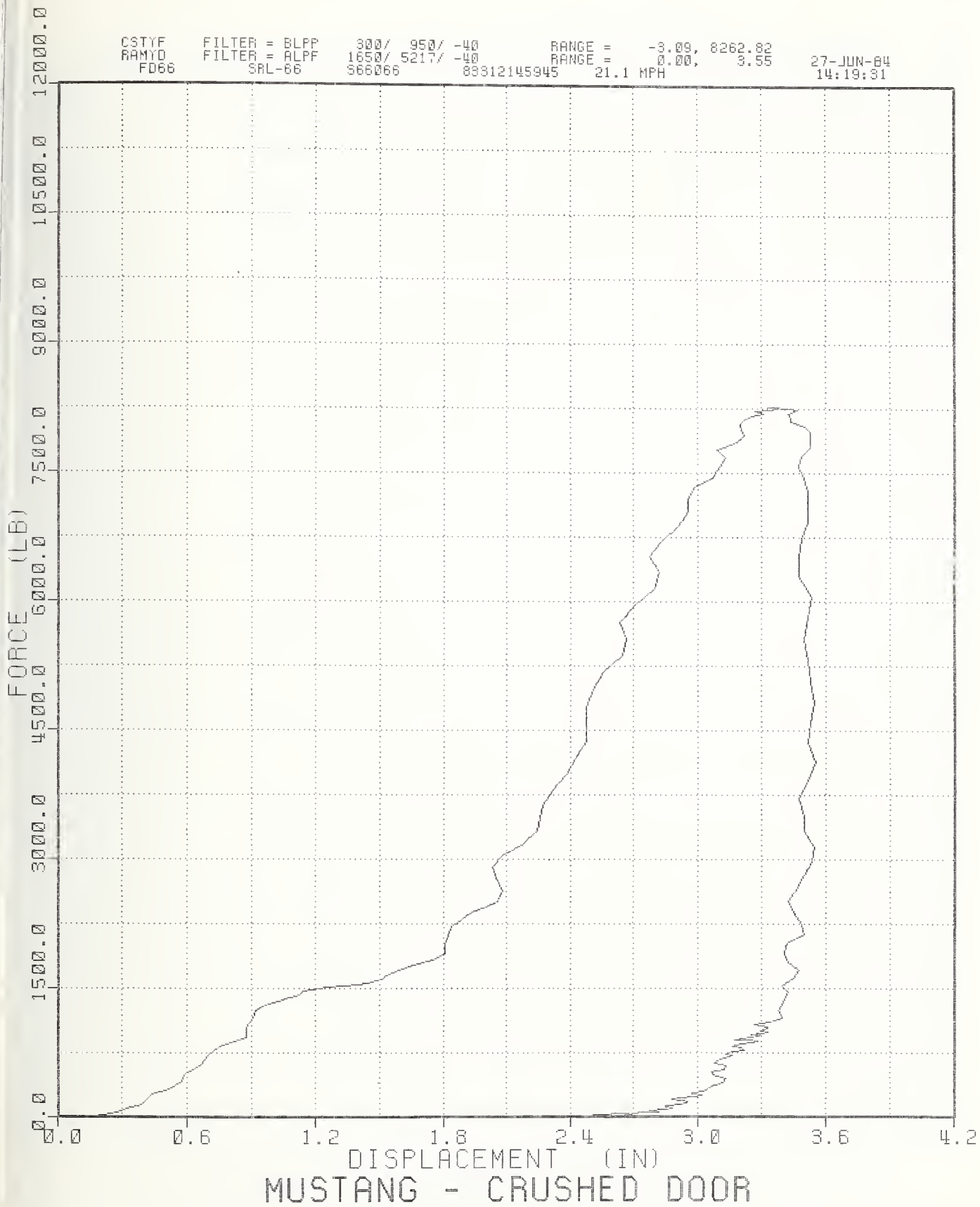
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 8.29 27-JUN-84
FD65 SRL-66 S66065 83311144311 21.4 MPH 14:19:31
FORCE (LB)
3200.0
2800.0
2400.0
2000.0
1600.0
1200.0
800.0
400.0
0.0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
DISPLACEMENT (IN)
MUSTANG - UNBACKED DOOR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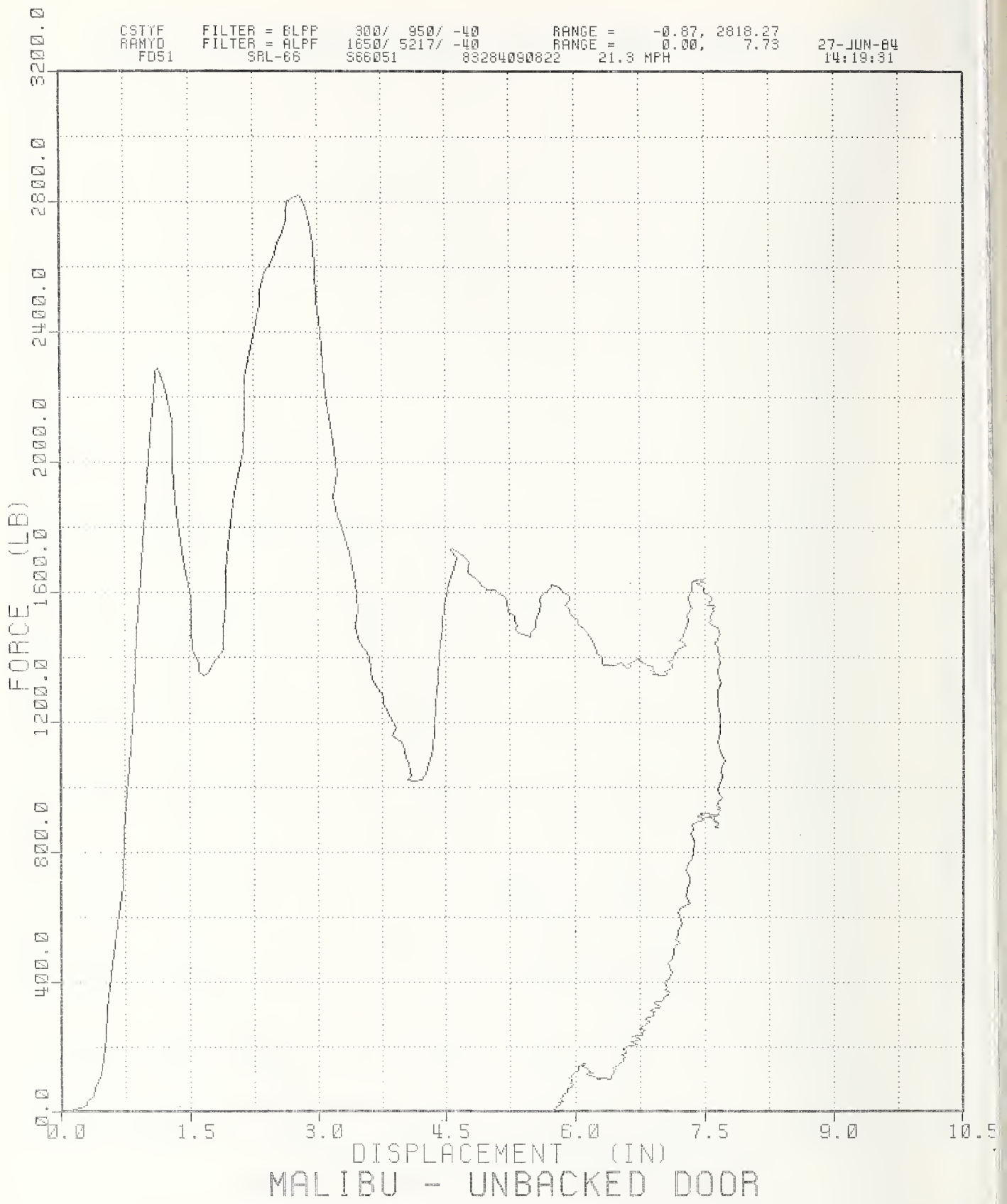
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 3.55 27-JUN-84
FD66 SRL-66 S66066 88312145945 21.1 MPH 14:19:31
FORCE (LB)
0.0
1500.0
3000.0
4500.0
6000.0
7500.0
9000.0
10500.0
12000.0
0.0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
DISPLACEMENT (IN)
MUSTANG - CRUSHED DOOR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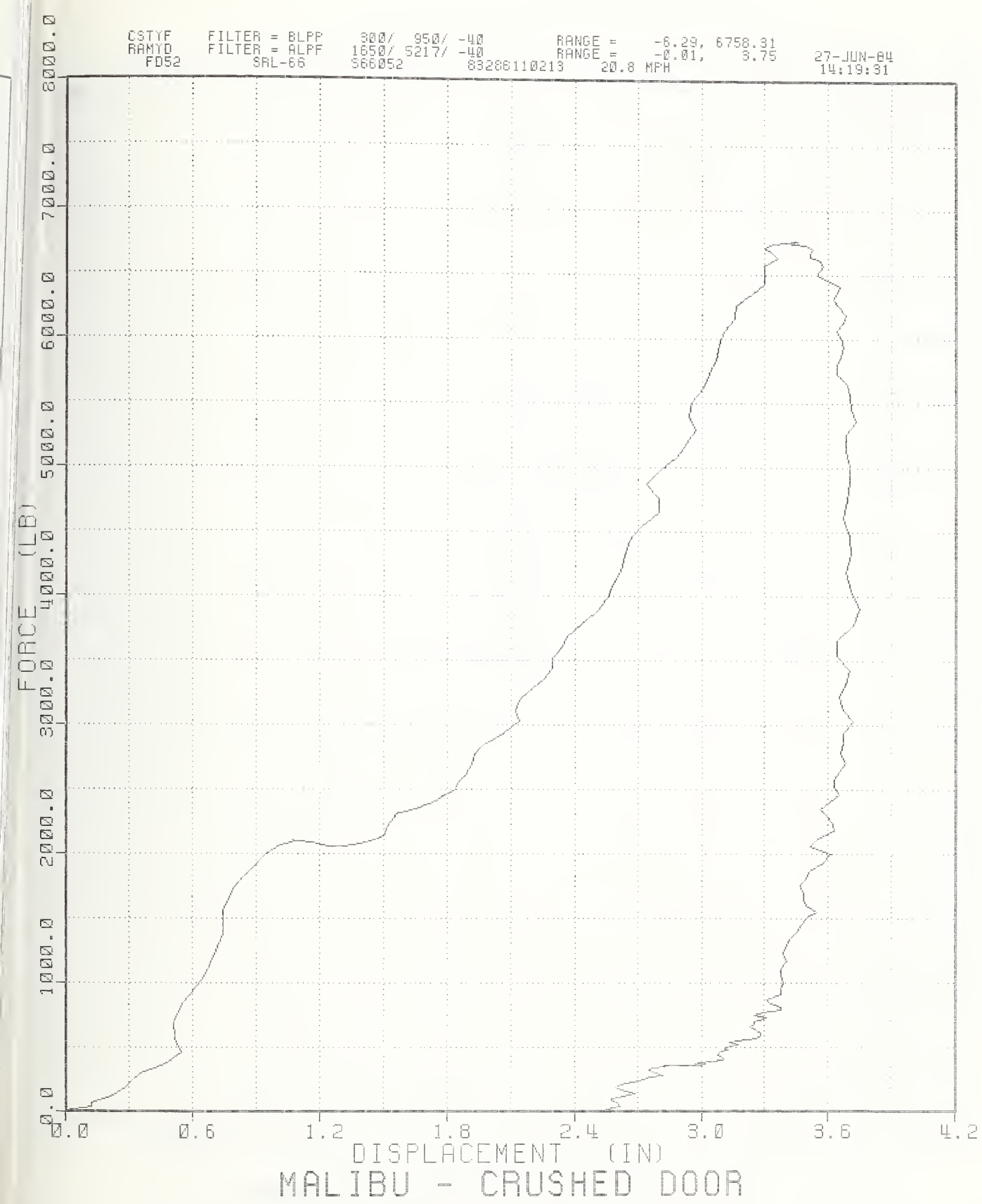
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 7.73 27-JUN-84
FD51 SRL-66 S66051 8328409082 21.3 MPH 14:19:31
FORCE (LB)
3200.0
2800.0
2400.0
2000.0
1600.0
1200.0
800.0
400.0
0.0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
DISPLACEMENT (IN)
MALIBU - UNBACKED DOOR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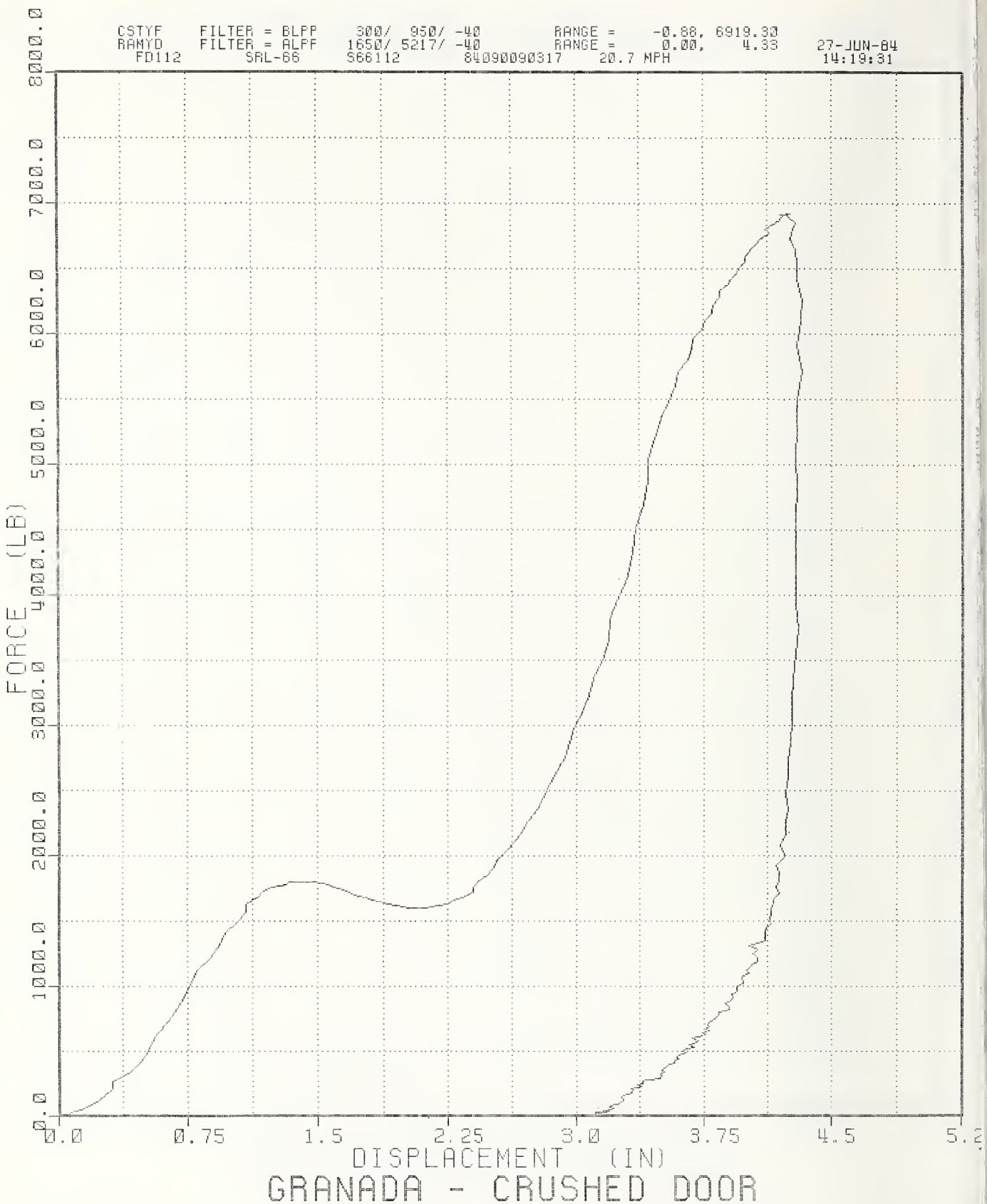
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = -0.01, 3.75
FD52 SRL-66 S68052 83288110213 20.8 MPH
27-JUN-84
14:19:31
FORCE (LB)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
8000.0
0.0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
DISPLACEMENT (IN)
MALIBU - CRUSHED DOOR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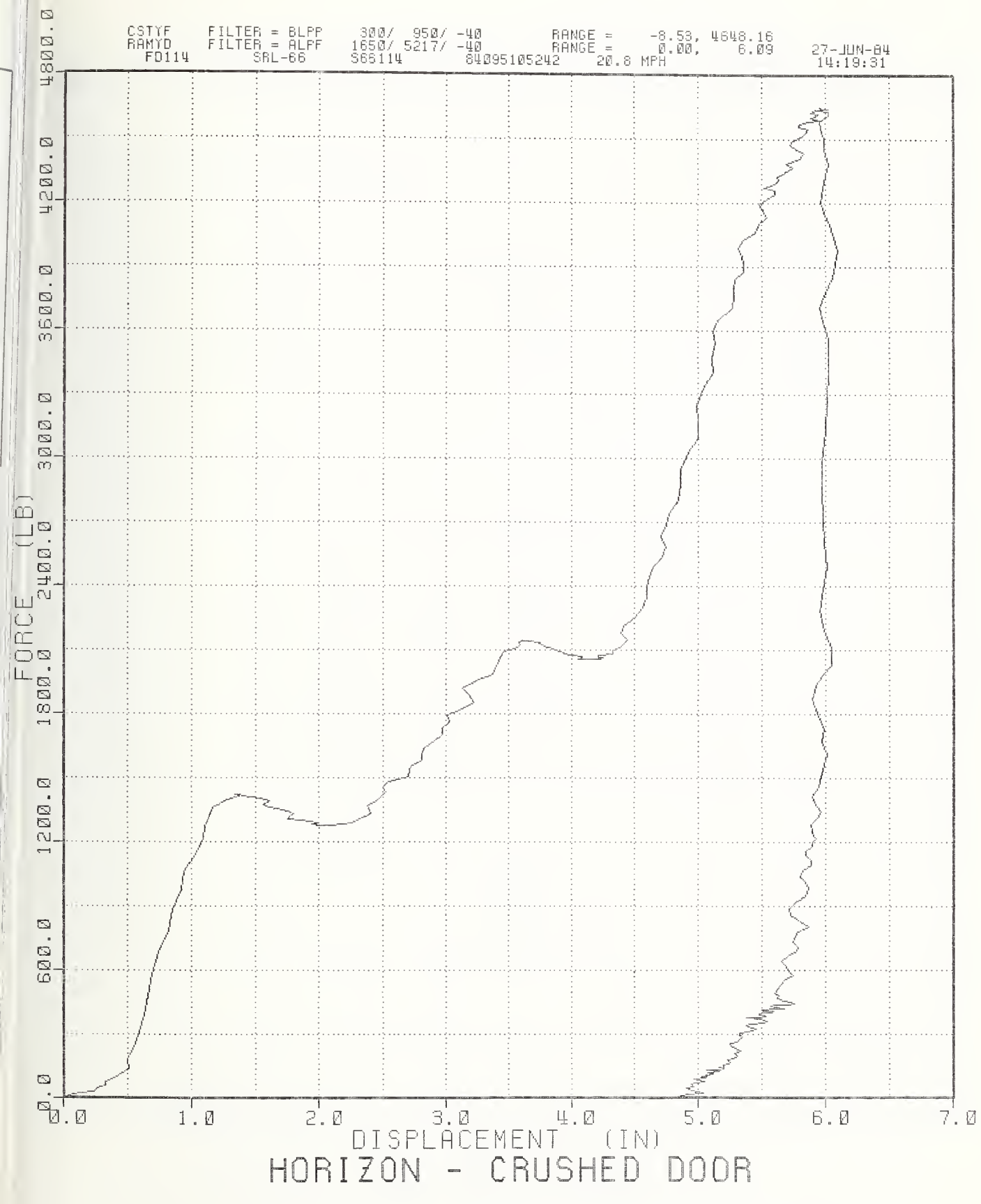
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 4.33
FD112 SRL-66 S66112 8409009031 7 20.7 MPH
27-JUN-84
14:19:31
FORCE (LB)
0.0
1000.0
2000.0
3000.0
4000.0
5000.0
6000.0
7000.0
8000.0
0.0
0.75
1.5
2.25
3.0
3.75
4.5
5.2
DISPLACEMENT (IN)
GRANADA - CRUSHED DOOR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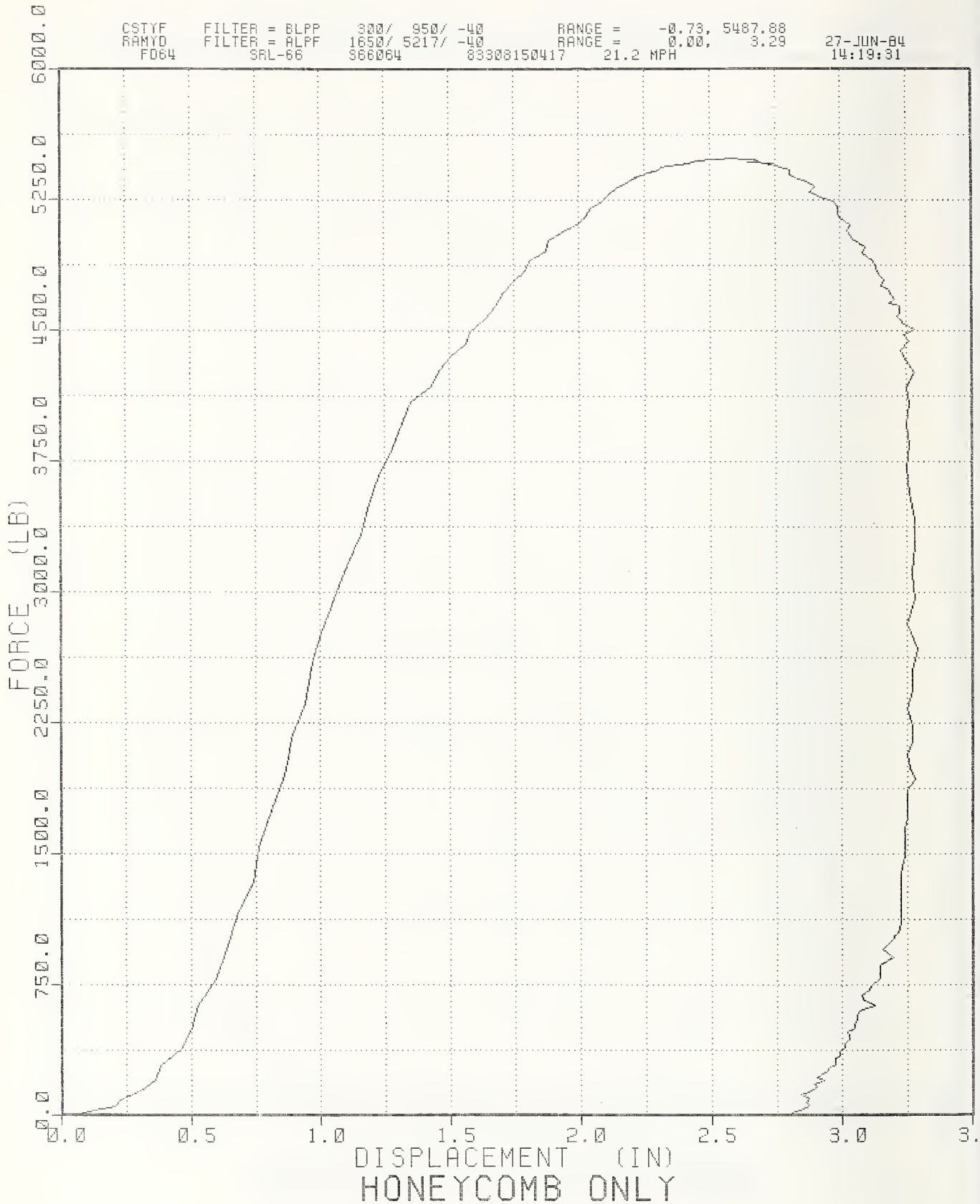
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 6.09
FD114 SRL-66 S65114 84095105242 20.8 MPH
27-JUN-84
14:19:31
FORCE (LB)
0.0
600.0
1200.0
1800.0
2400.0
3000.0
3600.0
4200.0
4800.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
DISPLACEMENT (IN)
HORIZON - CRUSHED DOOR


CSTYF FILTER = BLPP 300/ 950/ -40 RANGE = -0.73, 5487.88
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 3.29
FD64 SRL-66 S66064 83308150417 21.2 MPH
27-JUN-84
14:19:31
FORCE (LB)
0.0
750.0
1500.0
2250.0
3000.0
3750.0
4500.0
5250.0
6000.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
DISPLACEMENT (IN)
HONEYCOMB ONLY

PADDED VOLKSWAGEN RABBIT COMPONENT TEST RESULTS

Test Number 111 (rigid thorax):

S15 - 906	F15 - 1454	DRWT - 50.4
S20 - 892	F20 - 1751	DTM - 4.3
S25 - 870	F25 - 1982	DT3 - 3.5
S30 - 805	F30 - 1847	PCS - 928
SP - 804	VW - 1865	PCF - 5000

Test Number 110 (SID thorax):

ACCELERATION RESPONSES (g)

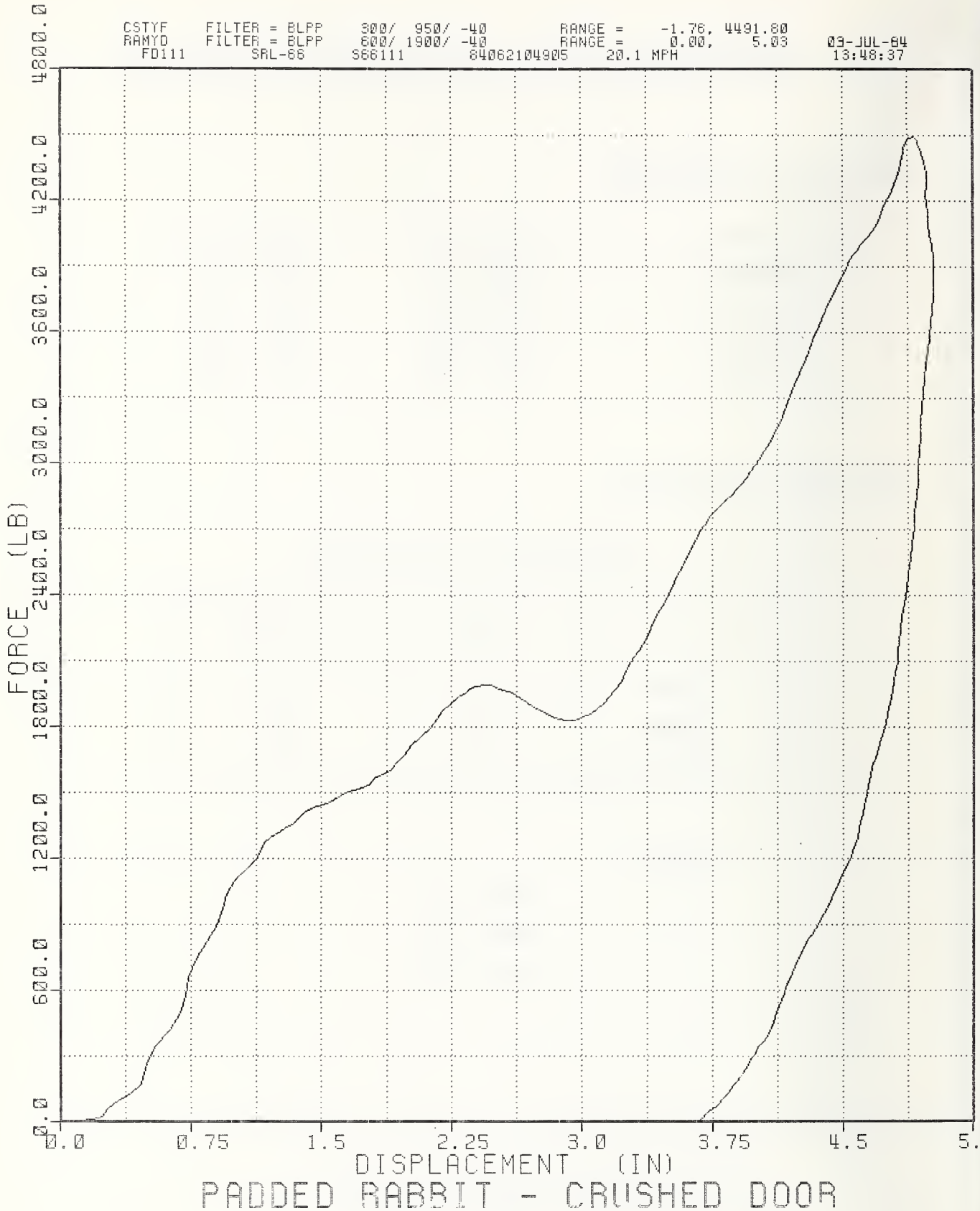
	RIBS	SPINE
UPPER	63.7	58.2
LOWER	79.6	57.7
AVERAGE	71.7	57.9

Therefore,

RIBA = 72

RIBM = 80

SPNA = 58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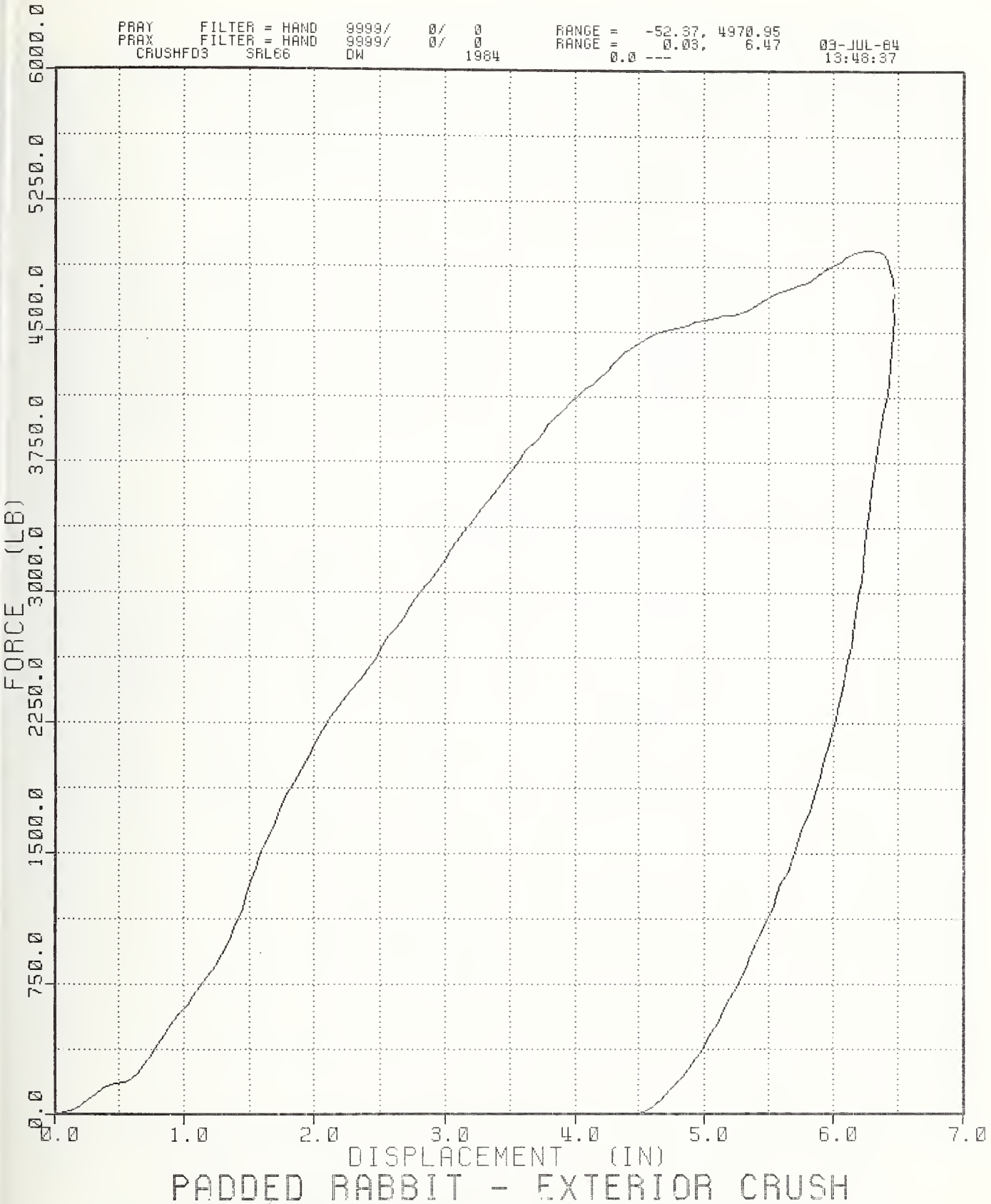
RAMYD FILTER = BLPP 600/ 1900/ -40 RANGE = 0.00, 5.03 09-JUL-84
FD111 SRL-66 S66111 840621049Ø5 20.1 MPH 13:48:37
FORCE (LB)
4800.0
4200.0
3600.0
3000.0
2400.0
1800.0
1200.0
600.0
0.0
0.0
0.75
1.5
2.25
3.0
3.75
4.5
DISPLACEMENT (IN)
PADDED RABBIT - CRUSHED DOOR



PADDED RABBIT - EXTERIOR CRUSH

4-DOOR HONDA CIVIC TEST RESULTS

Test Number 116 (rigid thorax component test):

S15 - 480	F15 - 1077	DRWT - 39.1
S20 - 559	F20 - 1190	DTM - 5.0
S25 - 570	F25 - 1548	DT3 - 4.0
S30 - 582	F30 - 1733	PCS - 995
SP - 775	VW - 1783	PCF - 4900

Test Number 840316 (side impact crash test):

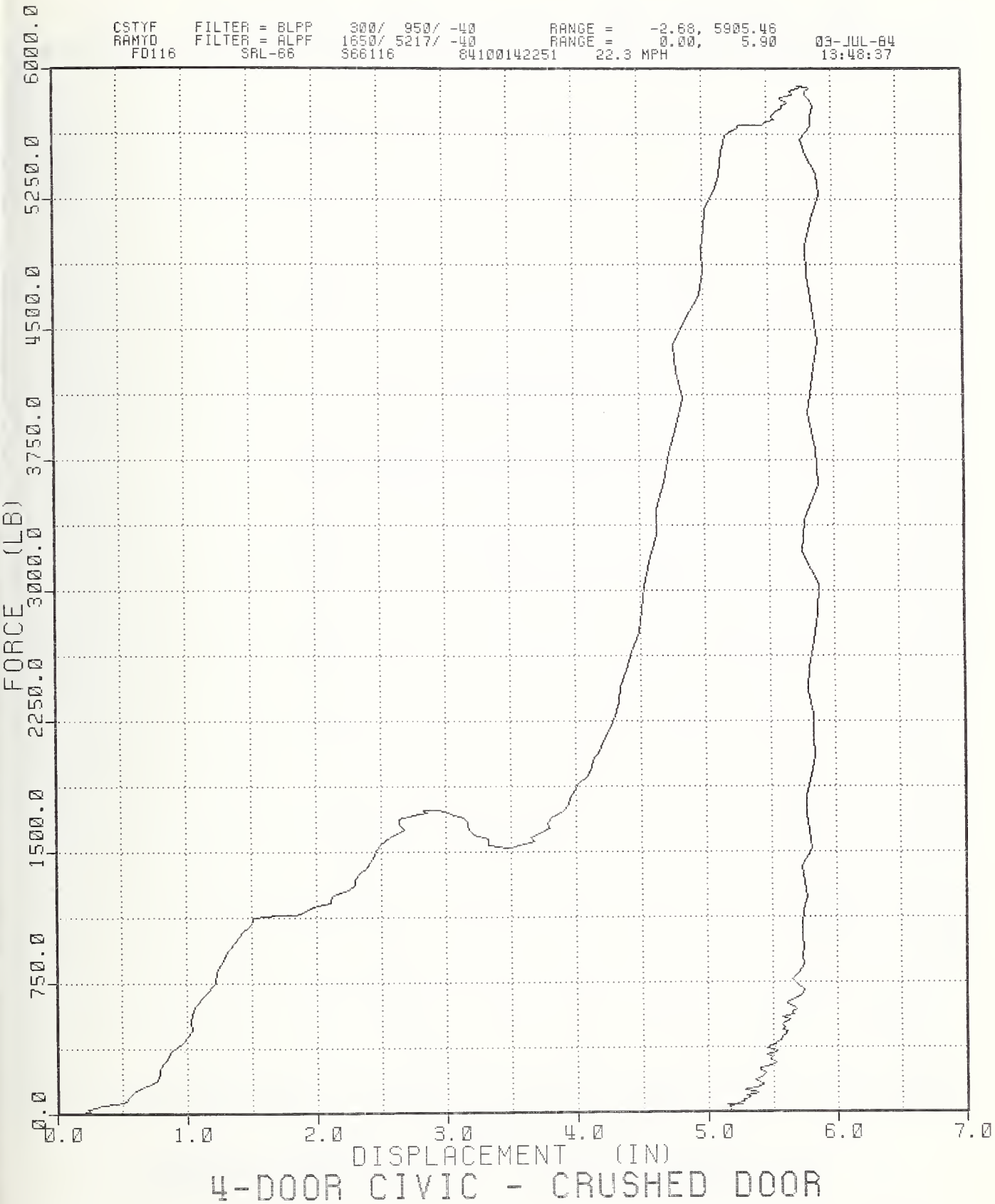
ACCELERATION RESPONSES (g)

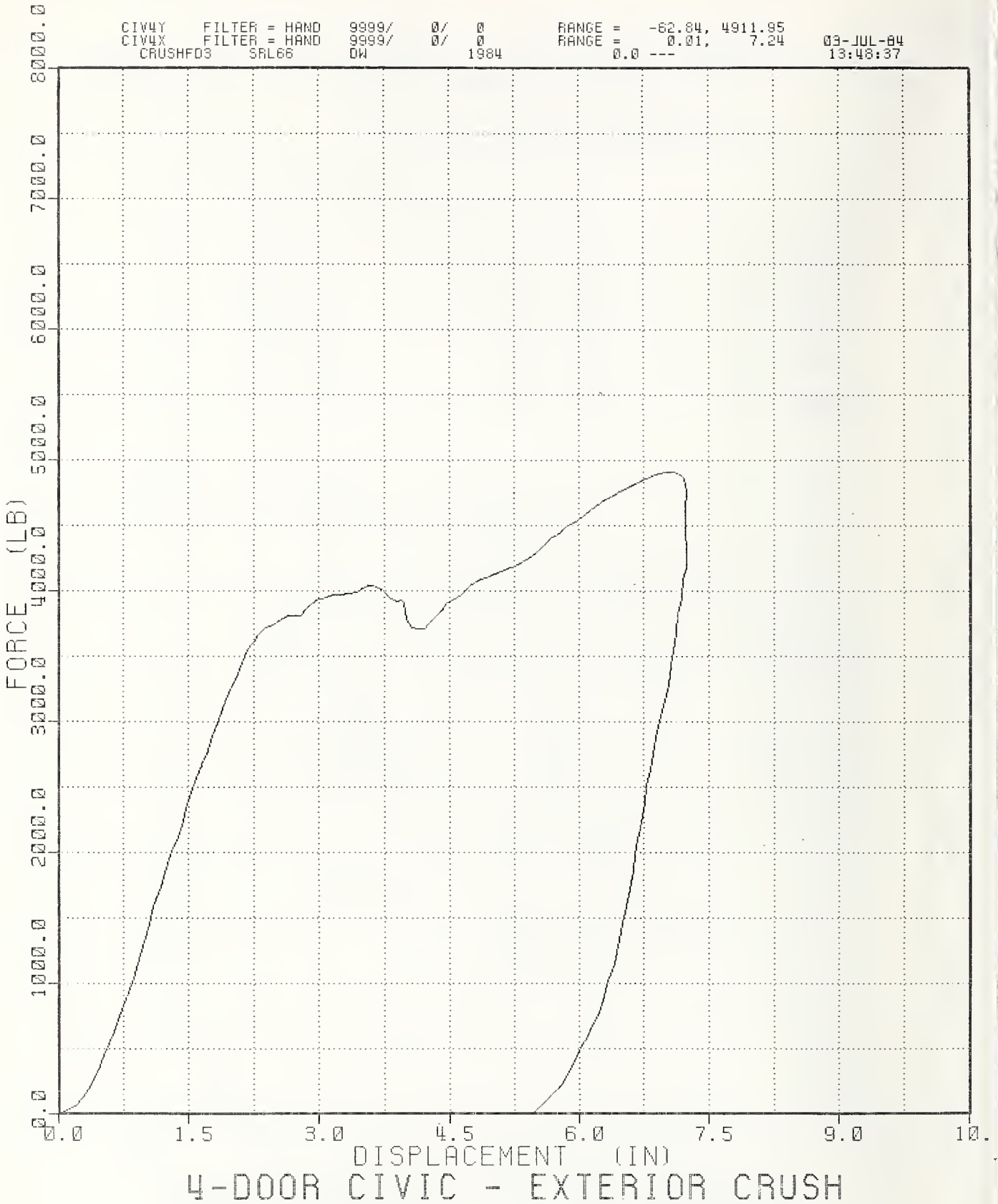
	RIBS	SPINE
UPPER	66.3	93.9
LOWER	63.8	94.4
AVERAGE	65.1	94.2

Therefore,

XRSA = 78

XRSM = 79


CSTYF FILTER = BLPP 300/ 950/ -40 RANGE = -2.68, 5905.46
RAMYD FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 5.90 03-JUL-84
FD116 SRL-66 S66116 84100142251 22.3 MPH 13:48:37
FORCE (LB)
0.0
750.0
1500.0
2250.0
3000.0
3750.0
4500.0
5250.0
6000.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
DISPLACEMENT (IN)
4-DOOR CIVIC - CRUSHED DOOR


CIV4Y FILTER = HAND 9999/ 0/ 0 RANGE = -62.84, 4911.95
CIV4X FILTER = HAND 9999/ 0/ 0 RANGE = 0.01, 7.24 03-JUL-84
CRUSHFD3 SRL66 DW 1984 0.0 --- 13:48:37
FORCE (LB)
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.
DISPLACEMENT (IN)
4-DOOR CIVIC - EXTERIOR CRUSH

APPENDIX B

Upper Interior Test Results

The seven vehicles chosen for the door area stiffness measurement tests were also chosen for the upper interior stiffness measurement tests. Rigid headform tests were performed on all seven vehicles and Part 572 headform tests were performed on all but the Ford Granada and the Plymouth Horizon. This section contains tables of the results of these tests, along with their test numbers.

Also in this section are force vs. deflection plots from the rigid headform tests and plots of the resultant head accelerations from the Part 572 headform tests.

In addition, a table is included for each car that lists gage thicknesses and lengths of the various upper structures impacted as well as data on the covers of these structures.

Finally, this section contains cross-section photographs of the various structures. The arrow on each indicates the direction and location of impact. Photographs showing some of the Rabbit test set-ups are also included.

STRUCTURAL STIFFNESS vs. HIC

VEHICLE	STRUCTURE	TEST NO.	STIFFNESS (lb/in)	SLOPE (lb/in)	INTERCEPT (lb)	TEST No.	HIC
RABBIT	SIDE ROOF RAIL	50	876	1414	-277	49	782
	A-PILLAR (upper)	57	1987	2787	-454	xx	xxxx
	A-PILLAR (lower #1)	56	1470	2049	-374	58	1698
	A-PILLAR (lower #2)	xx	xxxx	xxxx	xxxx	59	1523
	FRONT ROOF RAIL	62	356	603	-288	61	358
PHOENIX	B-PILLAR	35	1022	1530	-294	34	972
	SIDE ROOF RAIL	38	1607	1966	-170	39	1309
	A-PILLAR (upper)	40*	2387	3557	-529	44*	2024
	A-PILLAR (middle #1)	41	1675	2479	-484	43	1669
	A-PILLAR (middle #2)	45	1596	2401	-405	xx	xxxx
	A-PILLAR (lower)	42	1658	2513	-499	xx	xxxx
	FRONT ROOF RAIL	46	1015	1379	-190	47	640

* Cross-section hit was an overlap joint (i.e. double thickness sheet metal).

STRUCTURAL STIFFNESS vs. HIC

VEHICLE	STRUCTURE	TEST NO.	STIFFNESS (lb/in)	SLOPE (lb/in)	INTERCEPT (lb)	TEST No.	HIC
CIVIC	SIDE ROOF RAIL	76	726	886	-150	75	733
	A-PILLAR (upper)	77	1092	1485	-297	83	1204
	A-PILLAR (lower)	78	1043	1353	-247	80	1183
	FRONT ROOF RAIL	82	892	1247	-266	81	803
MUSTANG	SIDE ROOF RAIL	86	1521	2070	-288	87	1316
	A-PILLAR (upper)	94*	1443	2213	-480	88*	1871
	A-PILLAR (lower)	90	1656	2326	-425	89	1586
	FRONT ROOF RAIL	91	641	683	-41	93	399
MALIBU	SIDE ROOF RAIL	95	588	664	-83	96	648
	A-PILLAR (upper)	102	2557	3754	-578	97	2305
	A-PILLAR (lower)	99	2203	3160	-503	98	2215
	FRONT ROOF RAIL	100	631	1064	-365	101	589

* Cross-section hit was an overlap joint (i.e. double thickness sheet metal).

STRUCTURAL STIFFNESS vs. HIC

VEHICLE	STRUCTURE	TEST NO.	STIFFNESS (lb/in)	PREDICTED HIC	SLOPE (lb/in)	INTERCEPT (lb)
GRANADA	SIDE ROOF RAIL	117	838	812	1244	-340
	A-PILLAR (upper)	118*	2792	2623	4192	-601
	A-PILLAR (lower)	119	1570	1491	2259	-394
	FRONT ROOF RAIL	120	777	756	935	-138
HORIZON	B-PILLAR	123	1036	996	1496	-372
	SIDE ROOF RAIL	122	1197	1145	1654	-350
	A-PILLAR (upper)	124	1539	1462	2290	-497
	A-PILLAR (lower)	125	1039	998	1350	-265
	FRONT ROOF RAIL	121	947	913	1232	-181

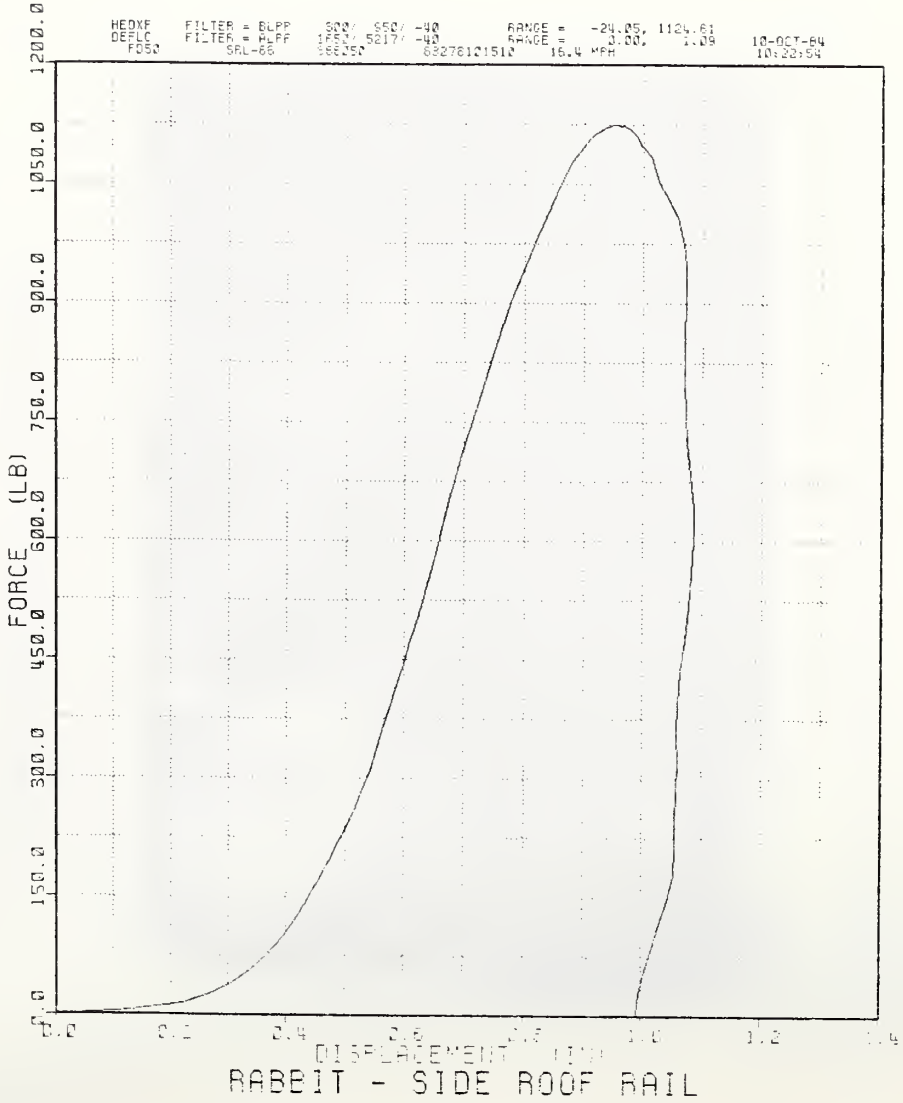
* Cross-section hit was an overlap joint (i.e. double thickness sheet metal).

A-pillar (upper) - 572 Headform

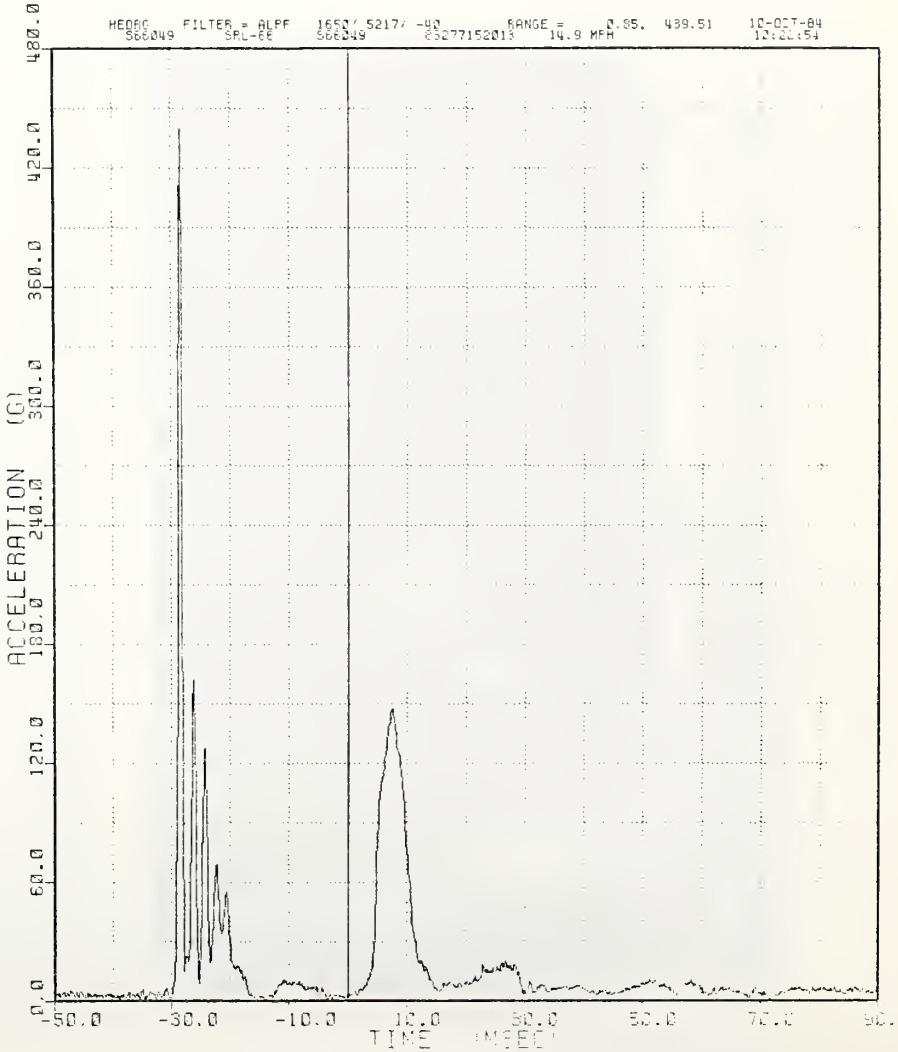
A-pillar (lower) - Rigid Headform

Side Roof Rail - 572 Headform

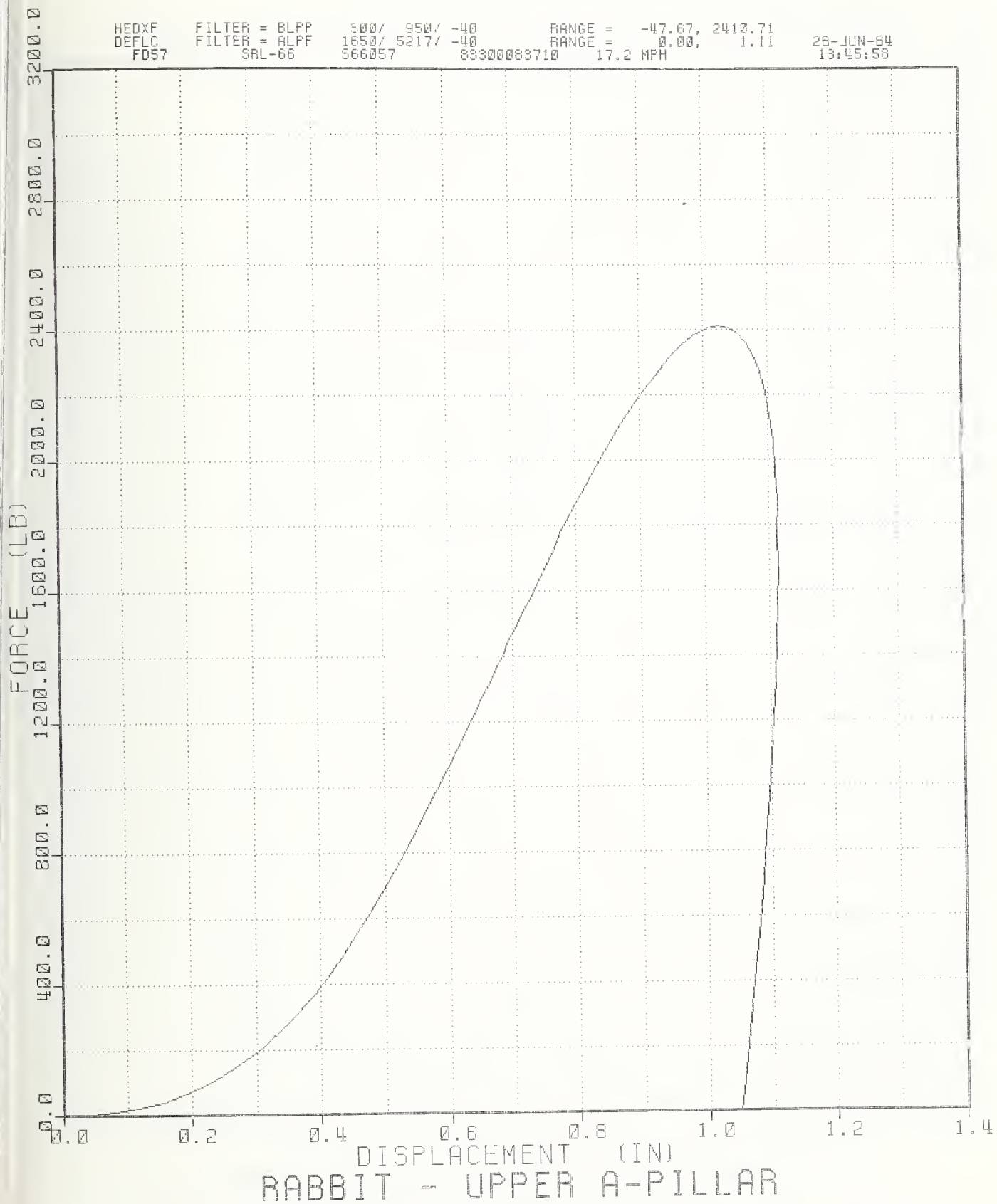
Front Roof Rail - 572 Headform

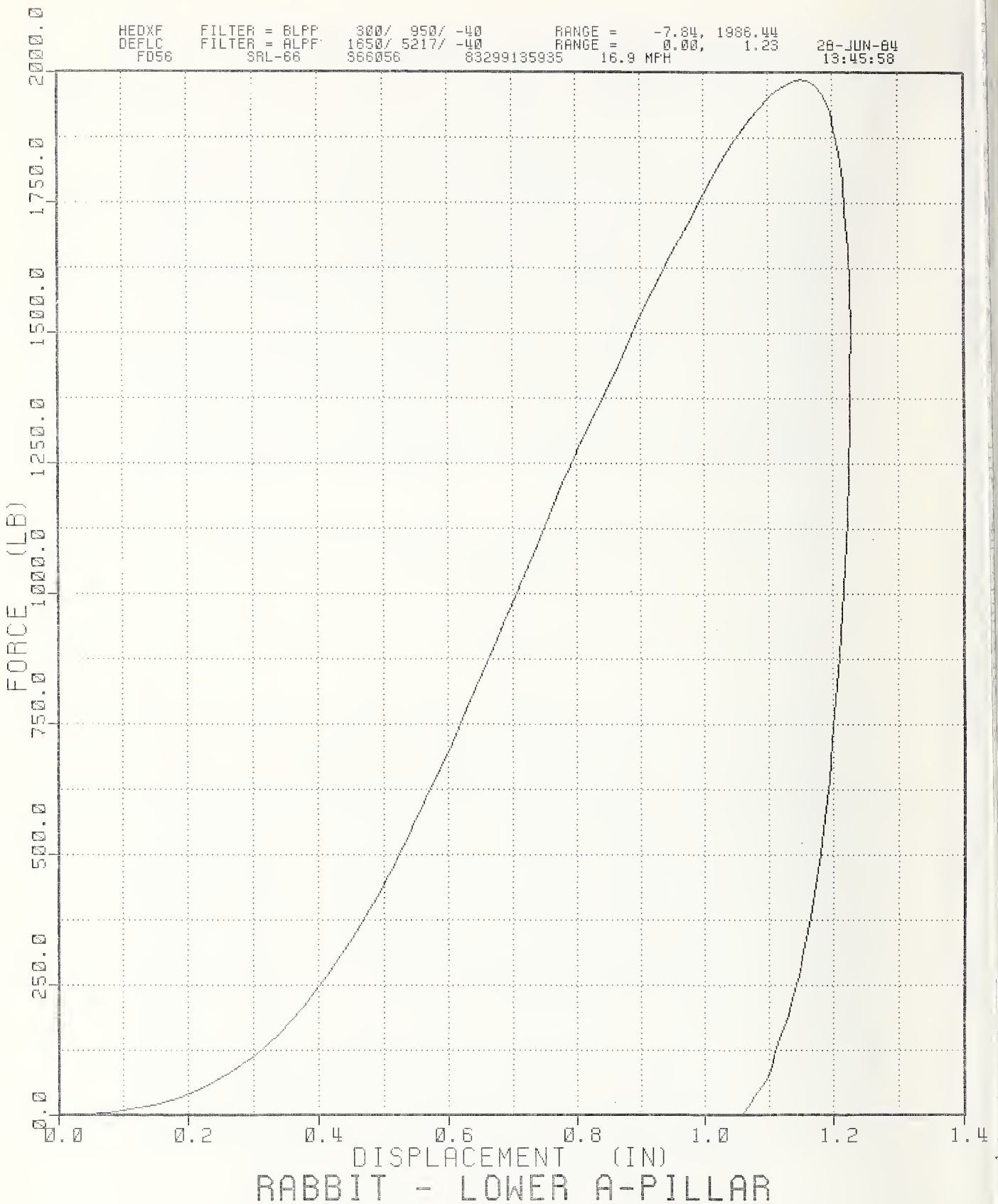


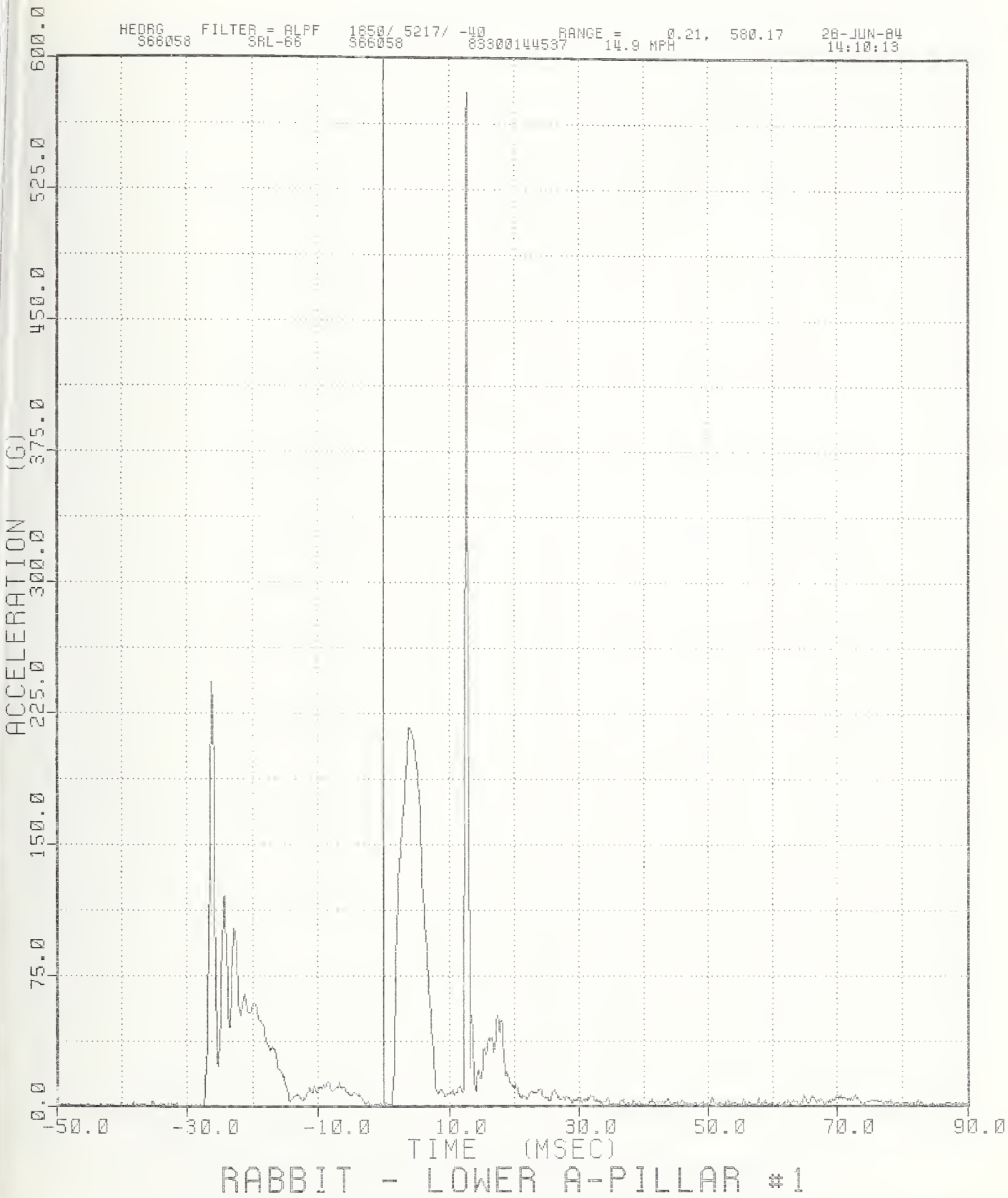
RABBIT - SIDE ROOF RAIL

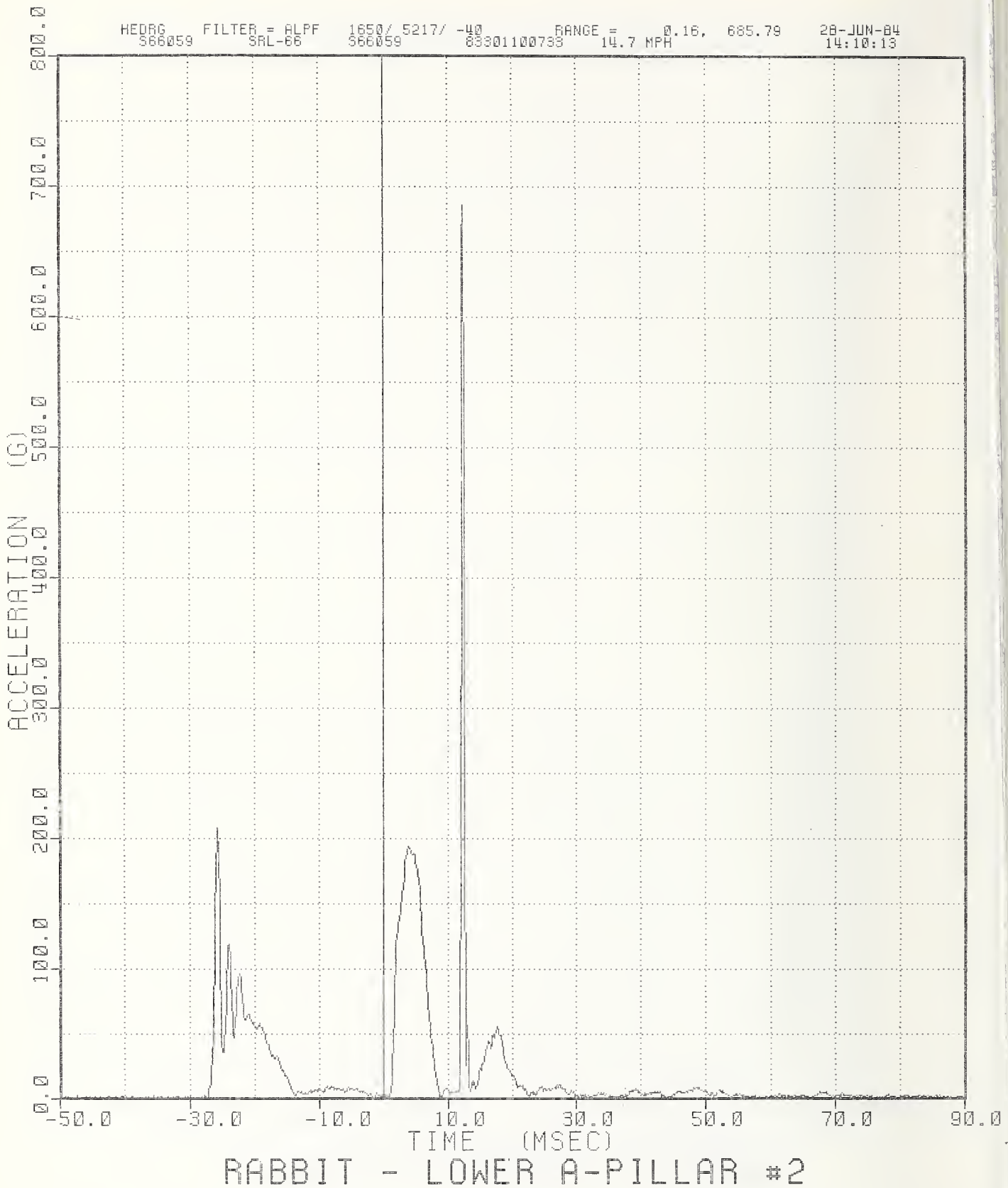


RABBIT - SIDE ROOF RAIL

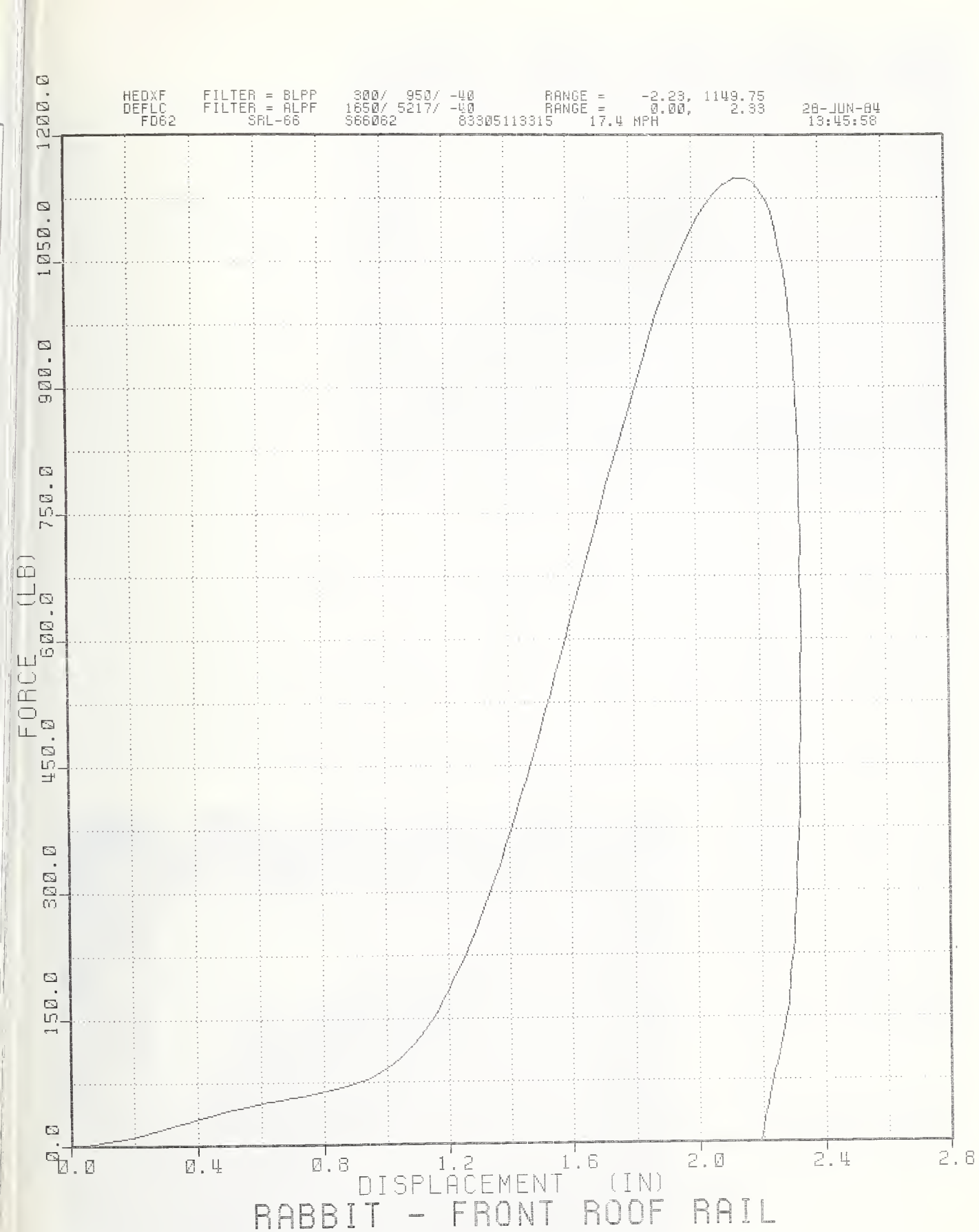

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -47.67, 2410.71
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.11 28-JUN-84
FD57 SRL-66 866057 83300083710 17.2 MPH 13:45:58
FORCE (LB)
0.0
400.0
800.0
1200.0
1600.0
2000.0
2400.0
2800.0
3200.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISPLACEMENT (IN)
RABBIT - UPPER A-PILLAR

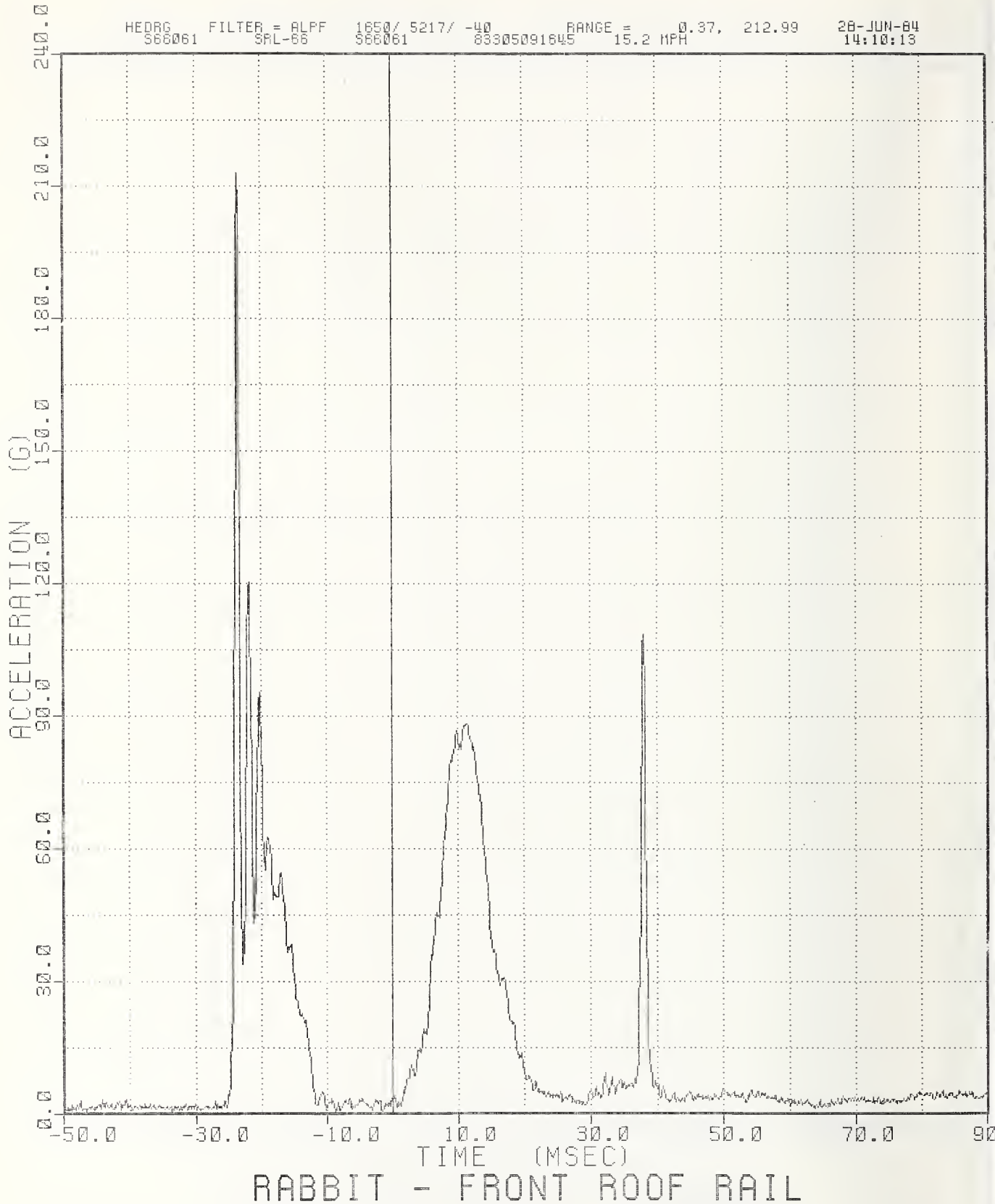

HEDXF FILTER = BLPF 300/ 950/ -40 RANGE = -7.84, 1986.44
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.23
FD56 SRL-66 S66056 83299135935 16.9 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISPLACEMENT (IN)
RABBIT - LOWER A-PILLAR


HEDRG FILTER = BLPF 1650/ 5217/ -40 RANGE = 0.21, 580.17 26-JUN-84
S66058 SRL-66 S66058 83300144537 14.9 MPH 14:10:13
ACCELERATION (G)
0.0
75.0
150.0
225.0
300.0
375.0
450.0
525.0
600.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
RABBIT - LOWER A-PILLAR #1



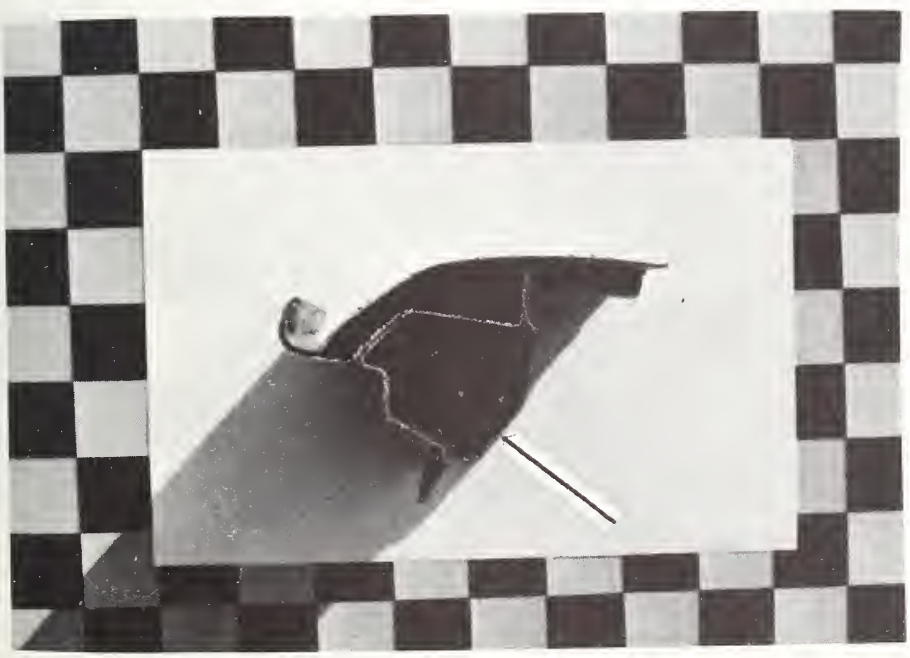
RABBIT - LOWER A-PILLAR #2


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -2.23, 1149.75
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 2.33 28-JUN-84
FD62 SRL-66 S66062 83305113315 17.4 MPH 13:45:58
FORCE (LB)
0.0
150.0
300.0
450.0
600.0
750.0
900.0
1050.0
1200.0
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
DISPLACEMENT (IN)
RABBIT - FRONT ROOF RAIL



RABBIT - FRONT ROOF RAIL

RABBIT
A-PILLAR



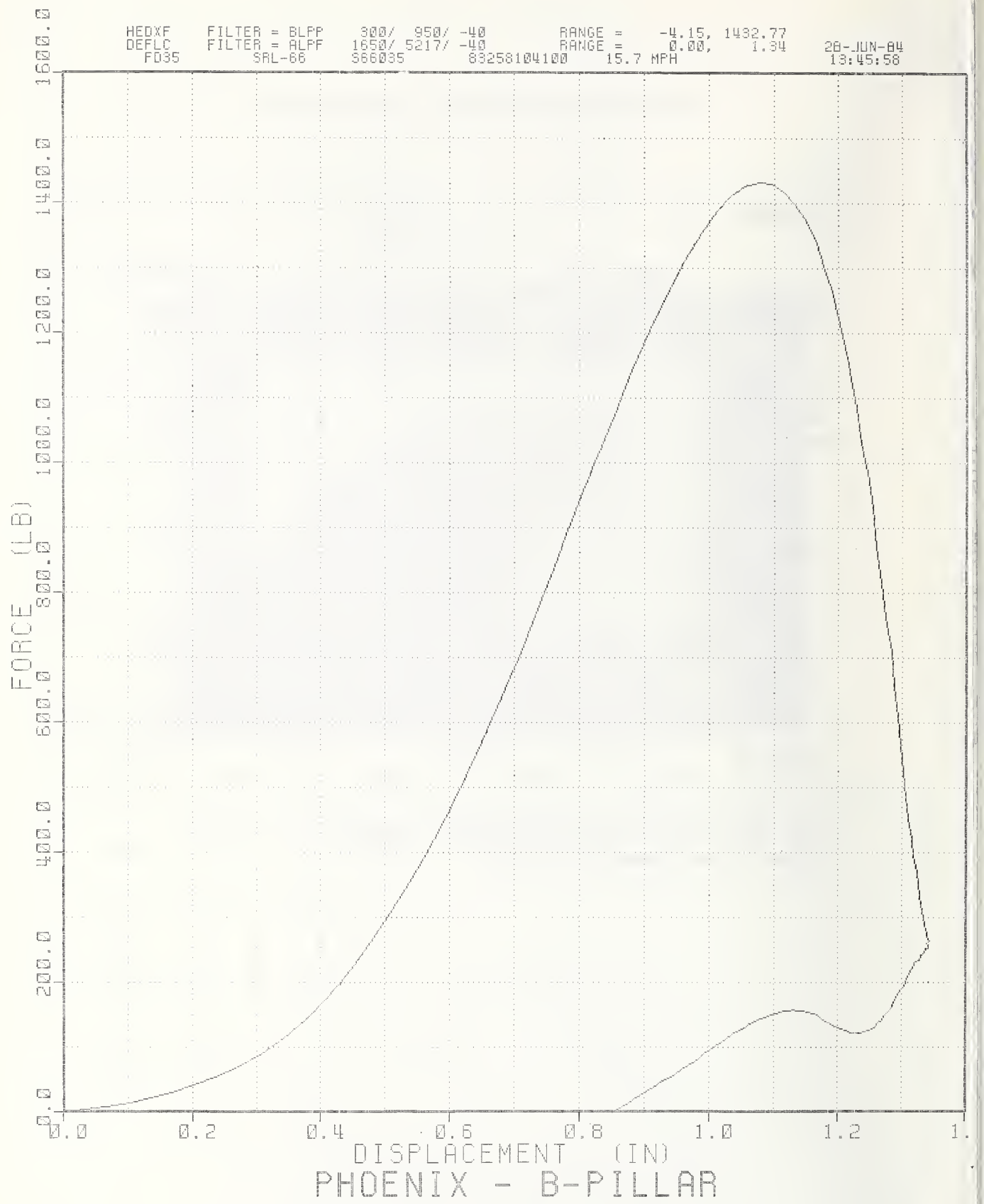
RABBIT
SIDE ROOF RAIL

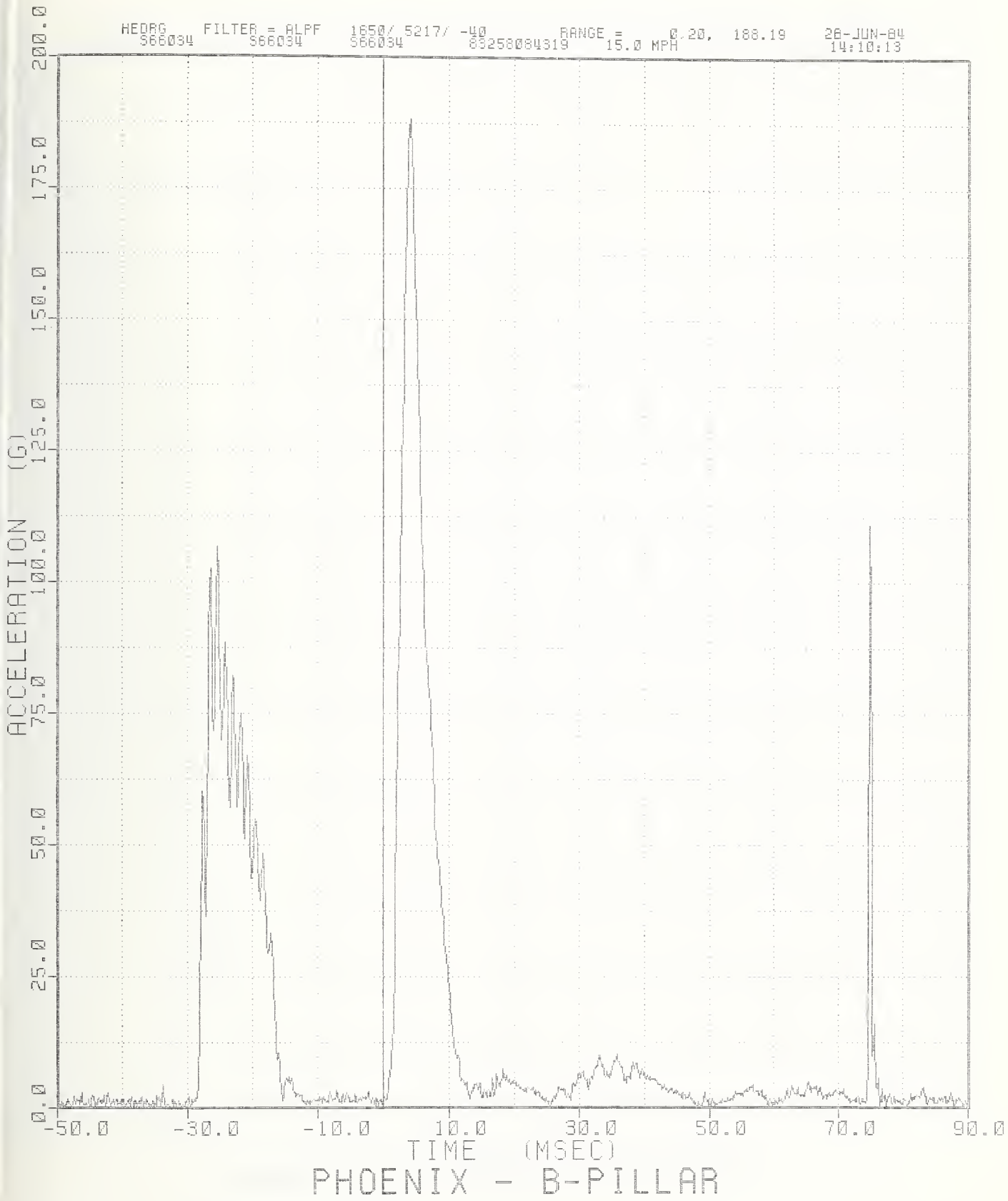
RABBIT FRONT ROOF RAIL

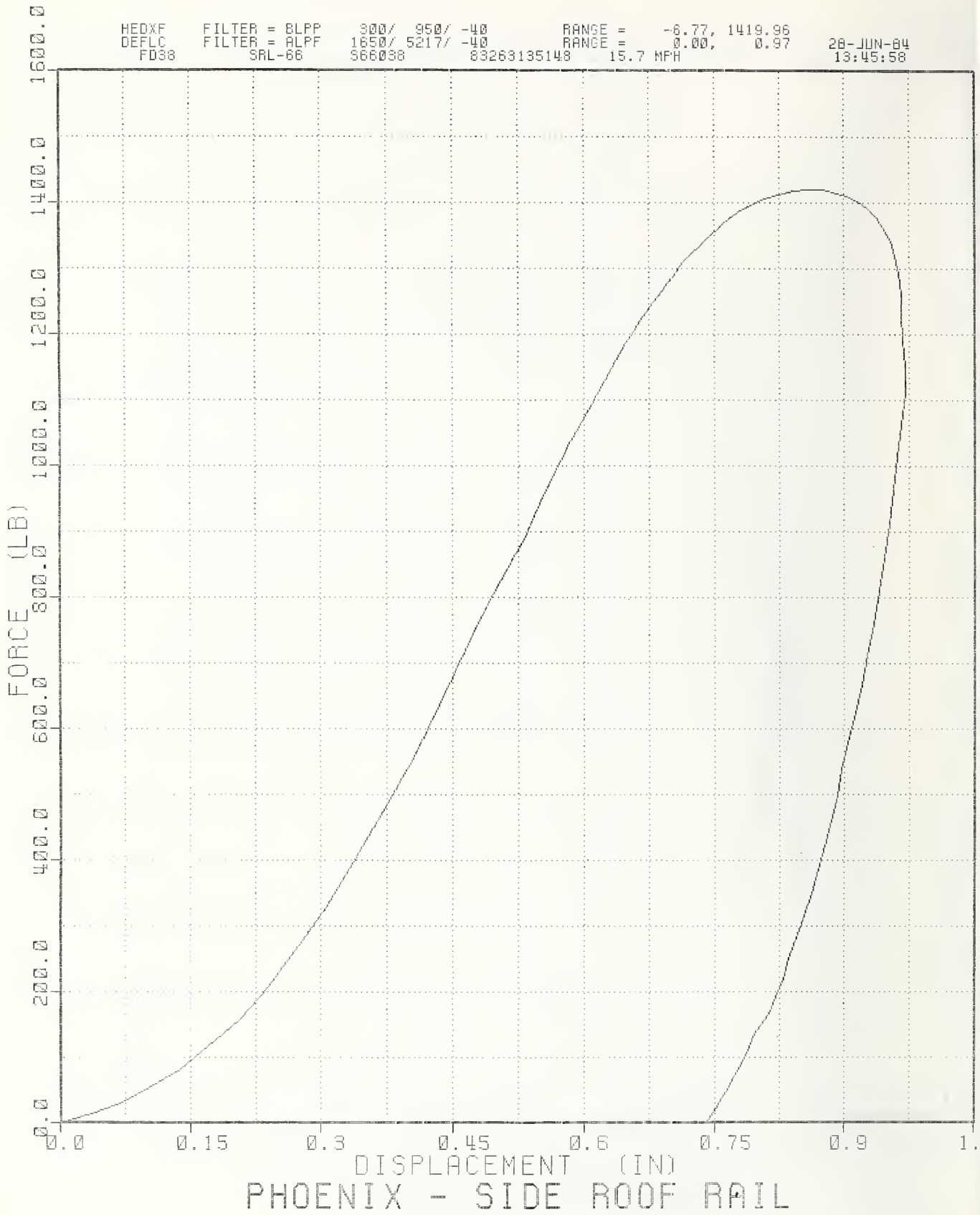
UPPER STRUCTURE MATERIAL AND COVER DATA

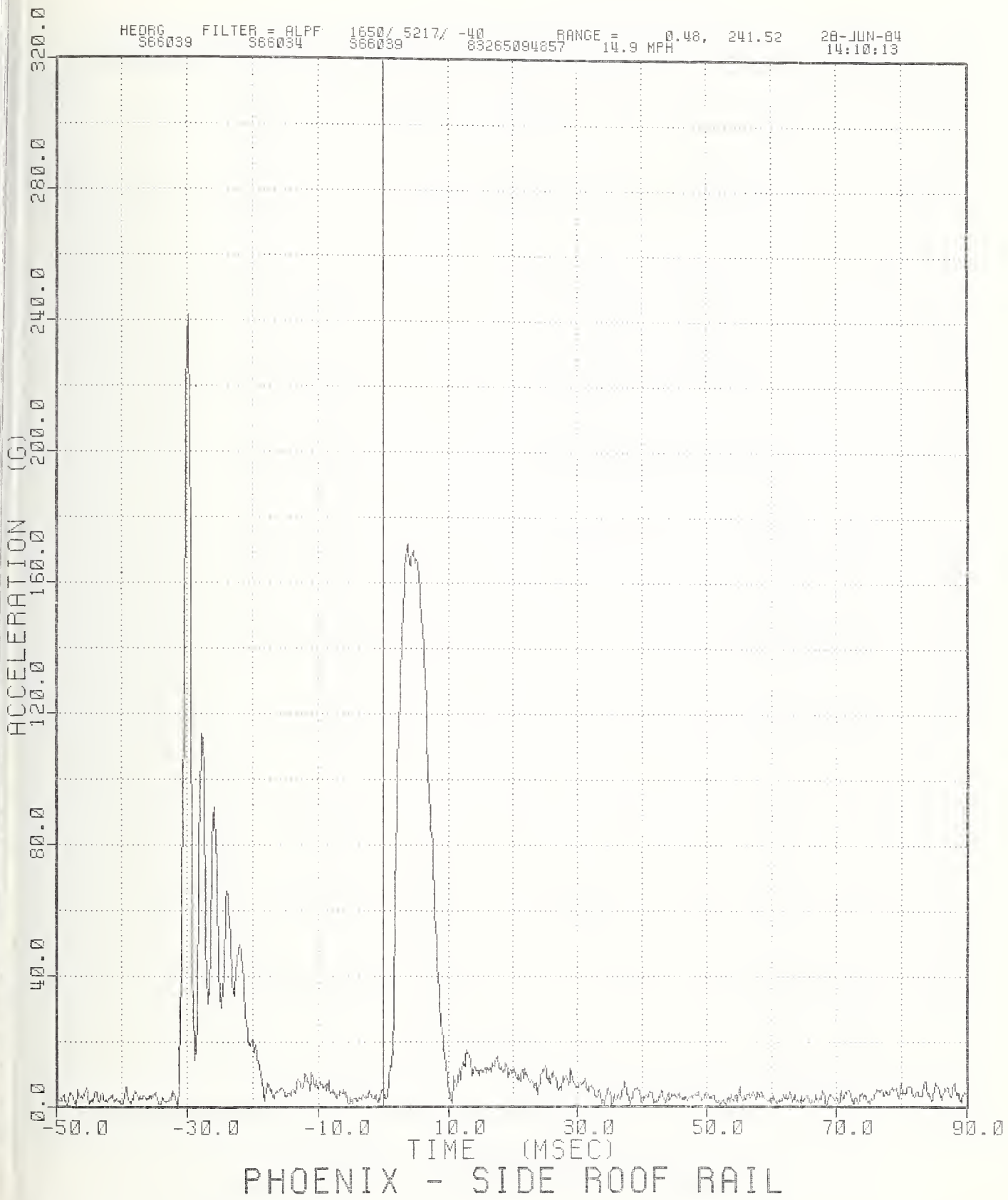
VEHICLE	RABBIT			
STRUCTURE	SHEET METAL GAGE THICKNESS*	COVER		STRUCTURE LENGTH
		TYPE OF MATERIAL	GAGE THICKNESS	
A-PILLAR	0.040"	felt/foam	1/8"	21"
SIDE ROOF RAIL	0.028"	felt/foam & cardboard	1/8" & 1/8"	28"
FRONT ROOF RAIL	0.028"	felt/foam & cardboard	1/8" & 1/8"	
B-PILLAR				

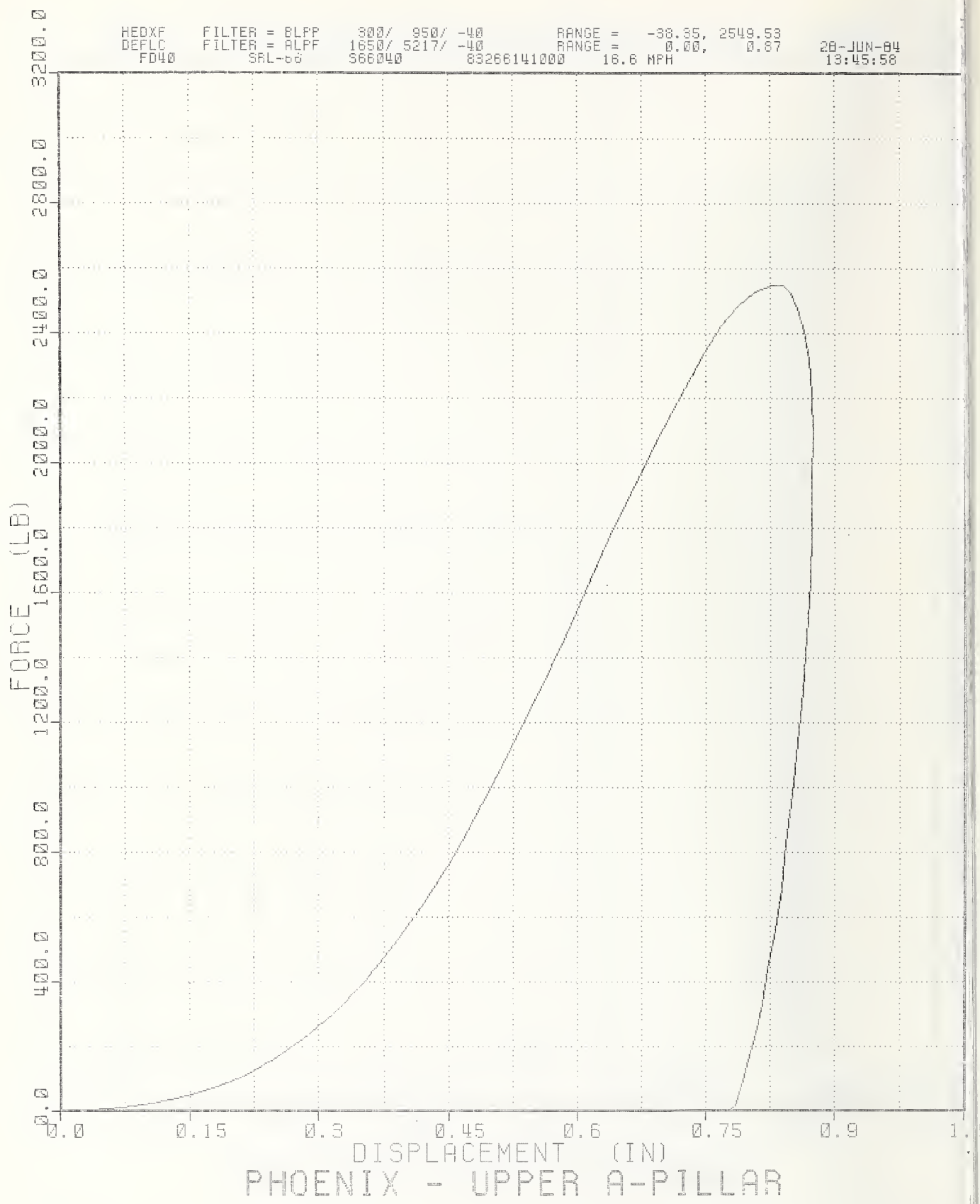
* If more than one gage thickness is listed, the first is that of the impacted surface.

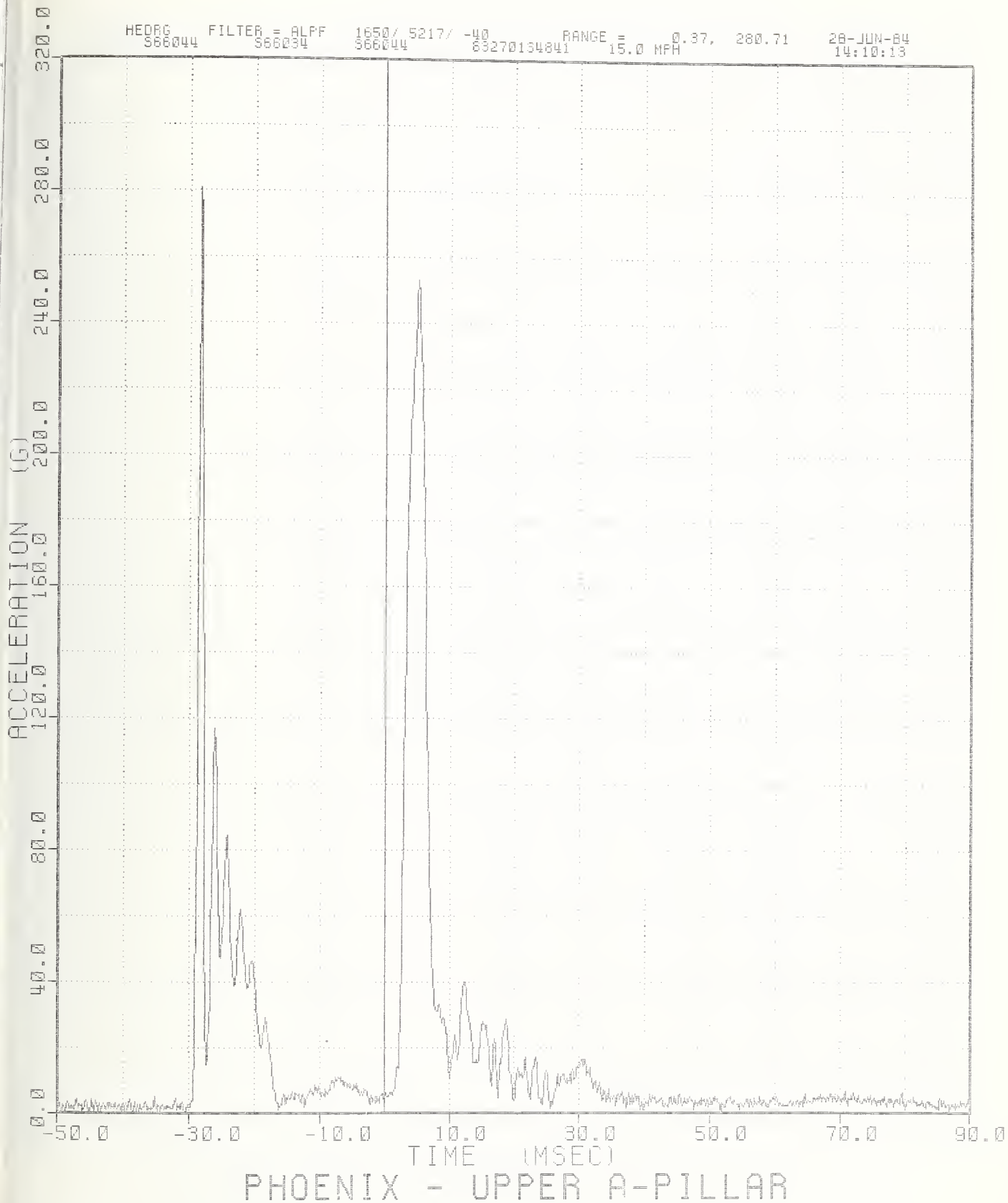

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -4.15, 1432.77
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.34 28-JUN-84
FD35 SRL-66 S66035 83258104100 15.7 MPH 13:45:58
FORCE (LB)
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
DISPLACEMENT (IN)
PHOENIX - B-PILLAR

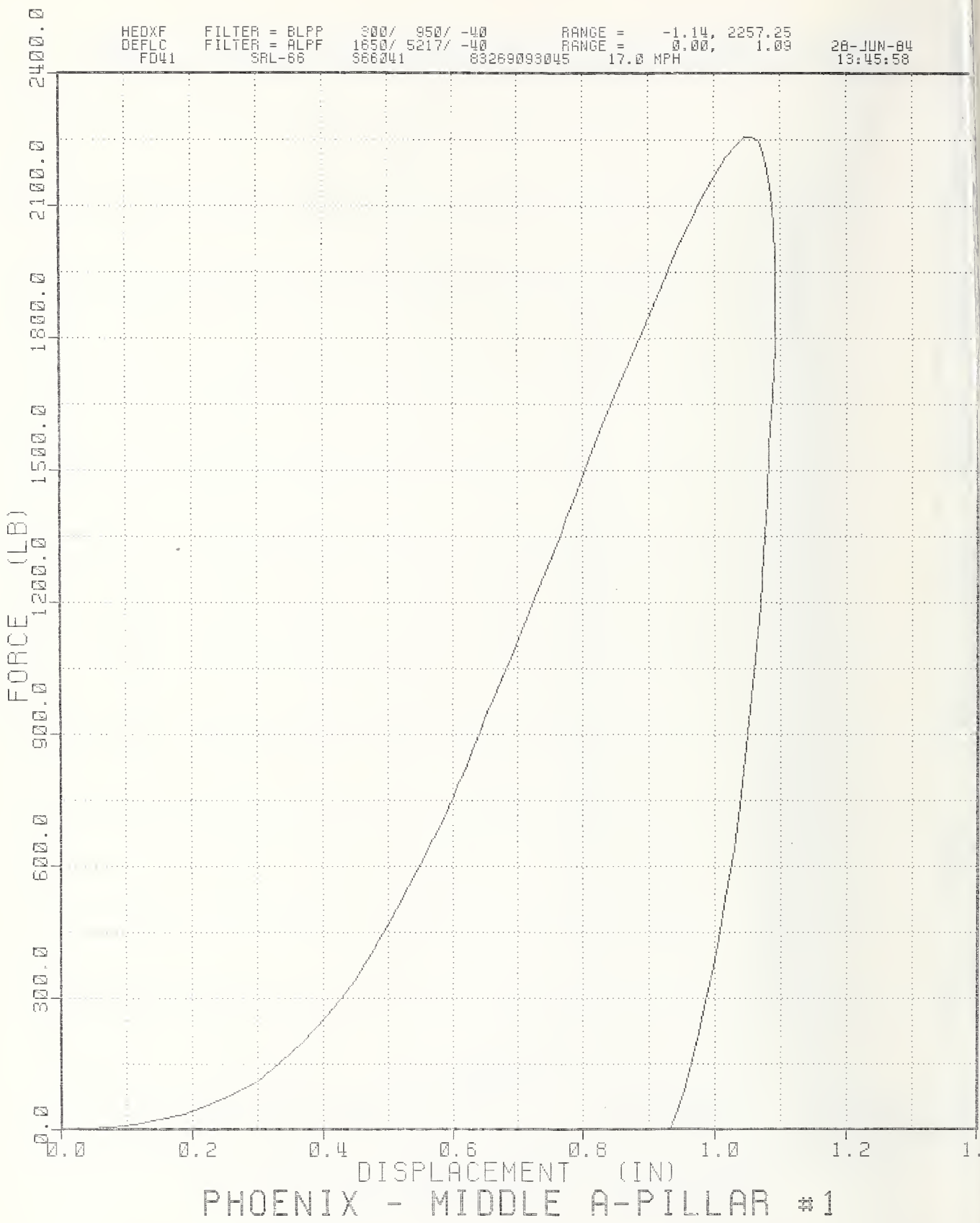

HEDRG S66034
FILTER = ALPF S66034
1650/ 5217/ -40 S66034
RANGE = 0.20, 188.19
83258084319
15.0 MPH
28-JUN-84
14:10:13
ACCELERATION (G)
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
PHOENIX - B-PILLAR

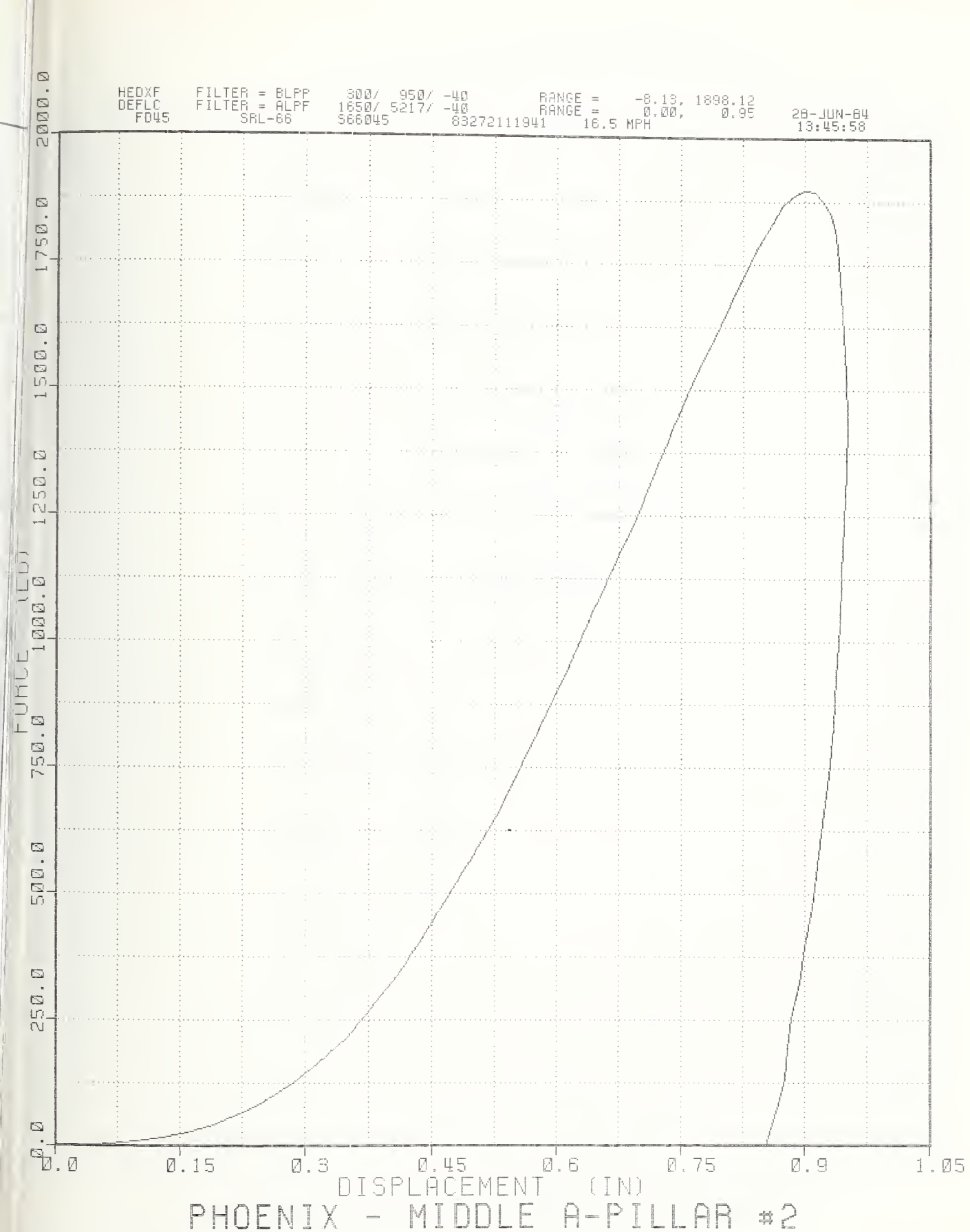

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -6.77, 1419.96
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 0.97 28-JUN-84
FD38 SRL-66 S66038 83263135148 15.7 MPH 13:45:58
FORCE (LB)
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
0.0
0.15
0.3
0.45
0.6
0.75
0.9
1.0
DISPLACEMENT (IN)
PHOENIX - SIDE ROOF RAIL


HEDRG S66039
FILTER = ALPF S66034
1650/ 5217/ -40 S66039
83265094857
RANGE = 0.48, 241.52
14.9 MPH
28-JUN-84
14:10:13
ACCELERATION (G)
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
PHOENIX - SIDE ROOF RAIL

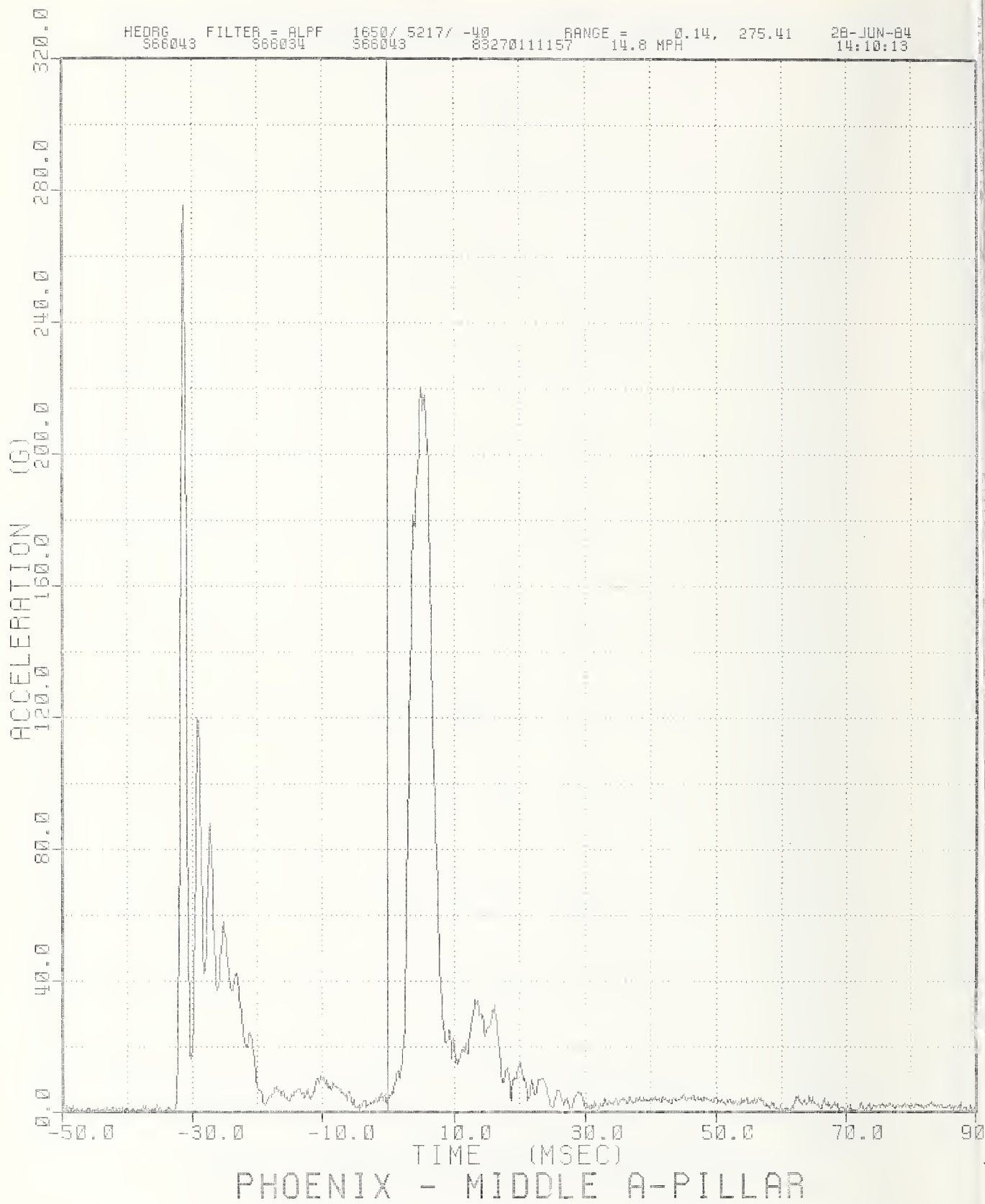

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -38.35, 2549.53
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 0.87
FD40 SAL-66 S66040 83266141000 16.6 MPH
28-JUN-84
13:45:58
FORCE (LB)
3200.0
2800.0
2400.0
2000.0
1600.0
1200.0
800.0
400.0
0.0
0.0
0.15
0.3
0.45
0.6
0.75
0.9
DISPLACEMENT (IN)
PHOENIX - UPPER A-PILLAR

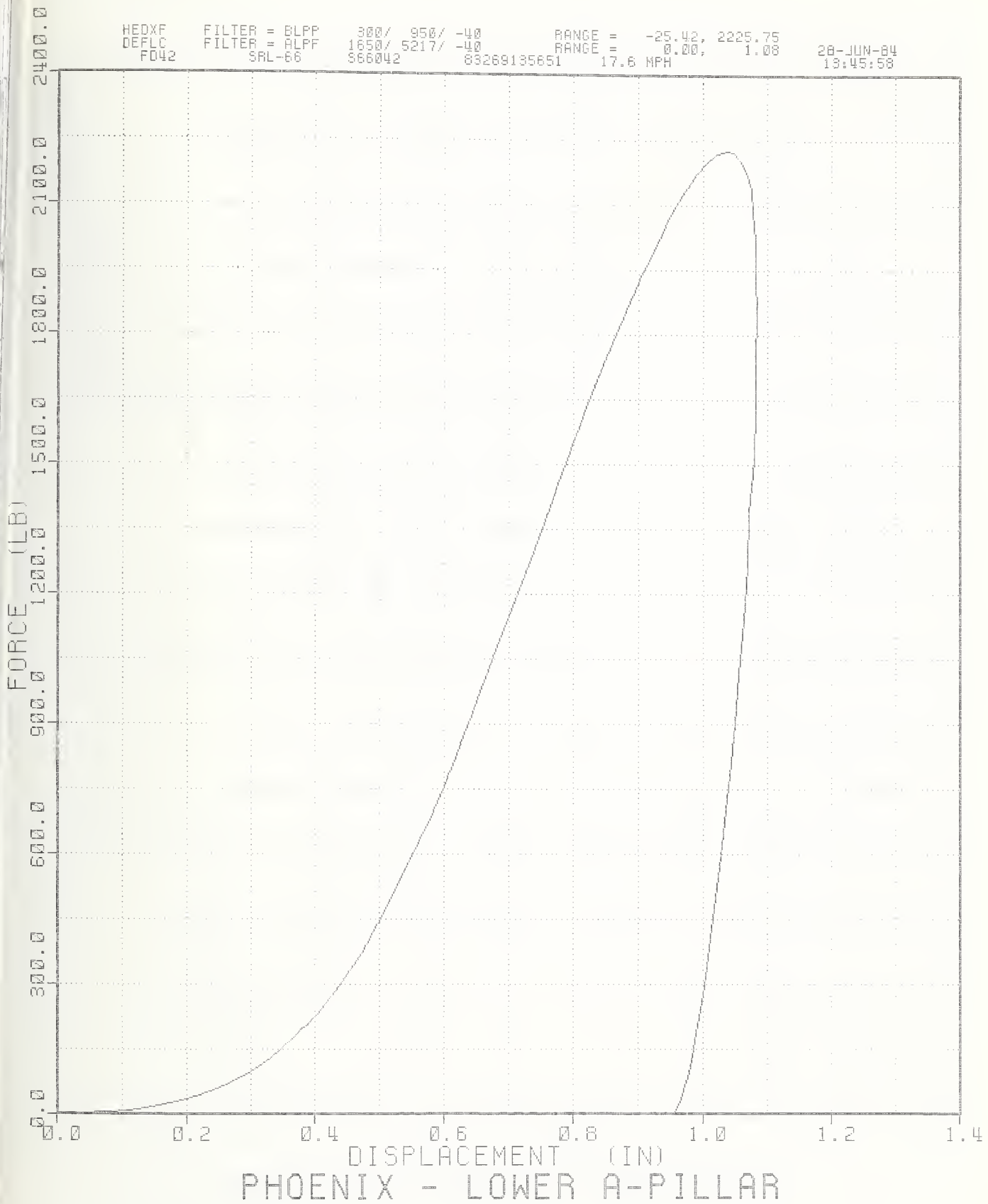

HEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.37, 280.71 28-JUN-84
S66044 S66034 S66044 63270134841 15.0 MPH 14:10:13
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
ACCELERATION (G)
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
PHOENIX - UPPER A-PILLAR

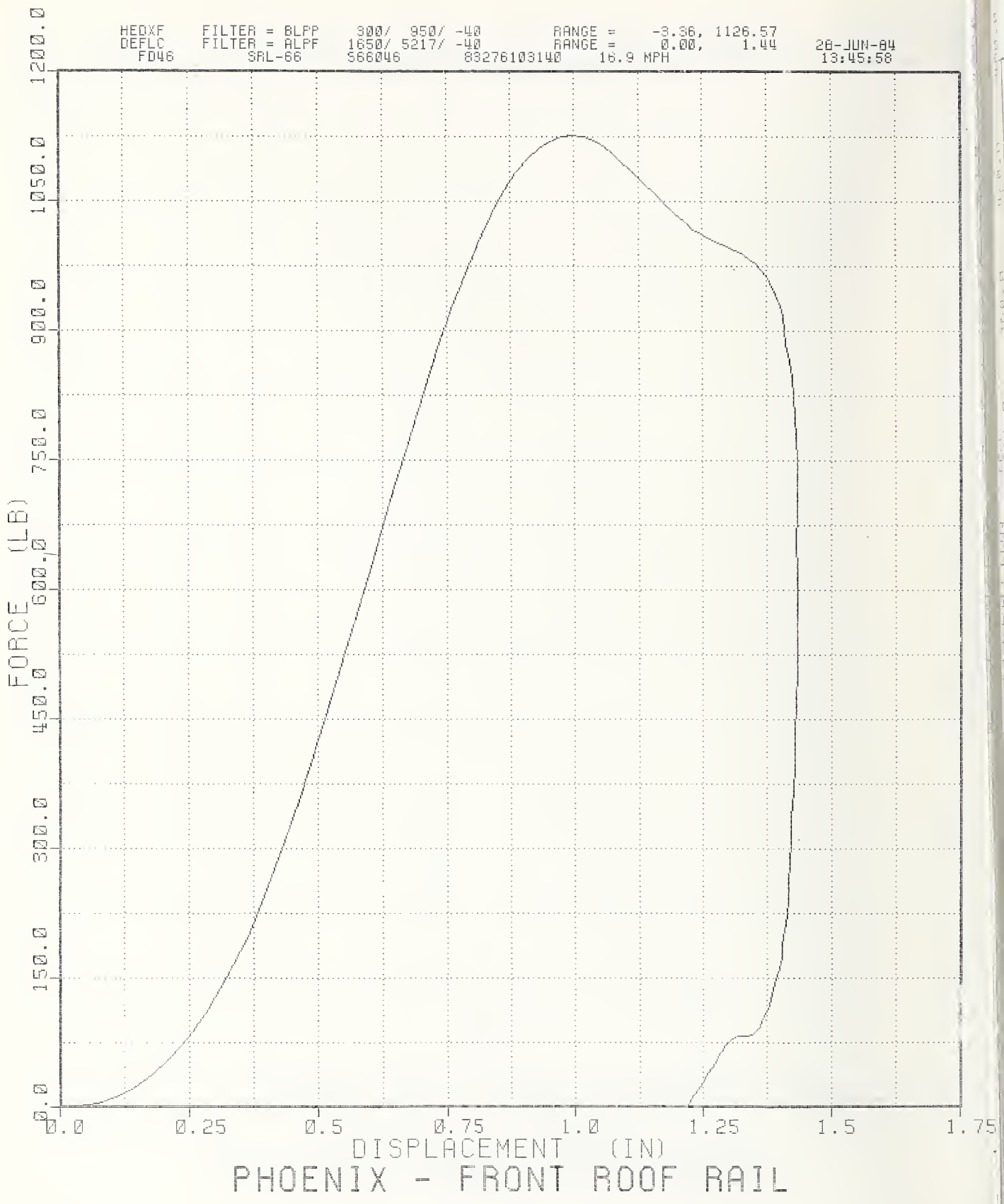

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -1.14, 2257.25
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.09
28-JUN-84
FD41 SRL-66 866041 83269093045 17.0 MPH
13:45:58
2400.0
2100.0
1800.0
1500.0
1200.0
900.0
600.0
300.0
0.0
FORCE (LB)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
DISPLACEMENT (IN)
PHOENIX - MIDDLE A-PILLAR #1

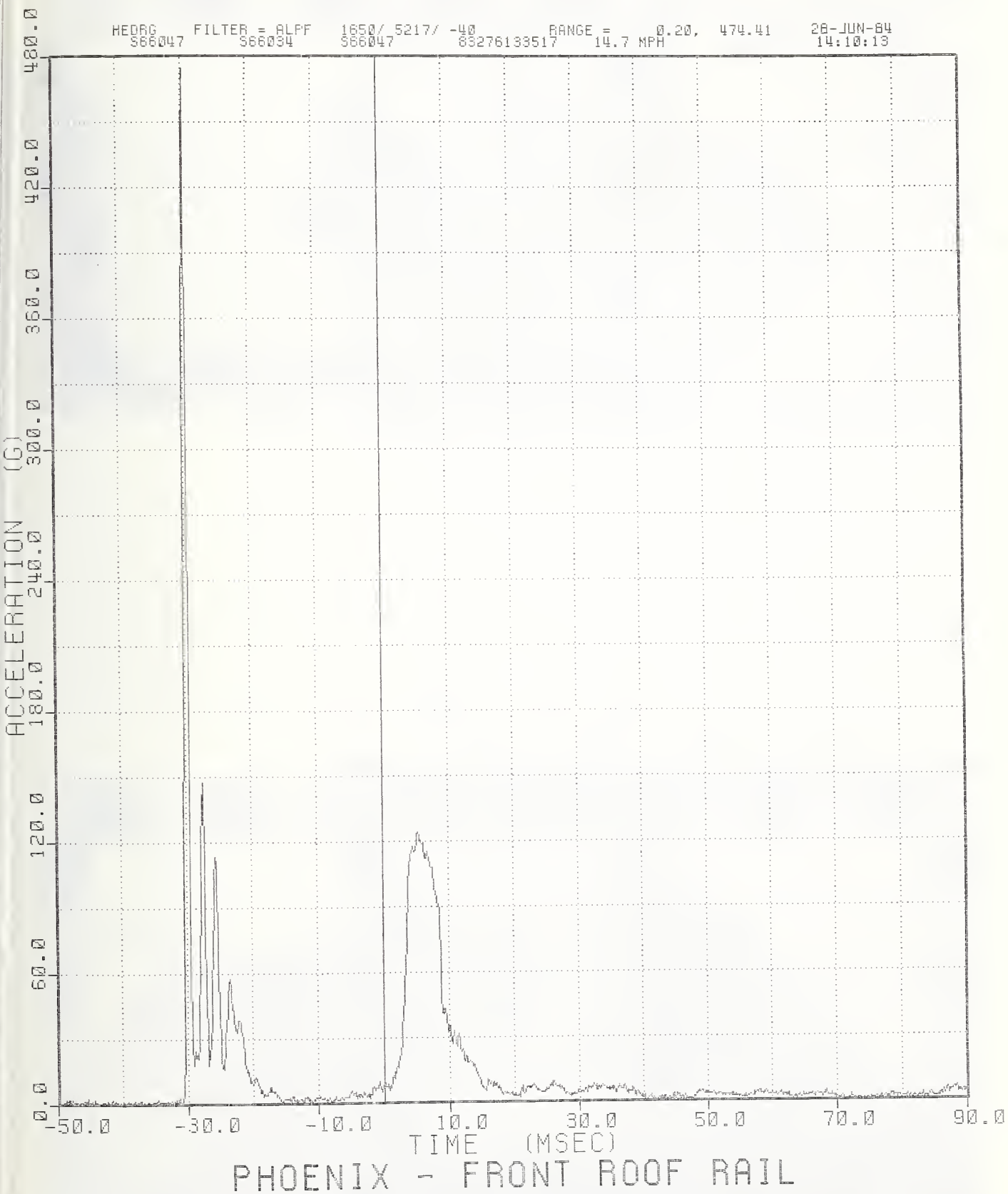


PHOENIX - MIDDLE A-PILLAR #2

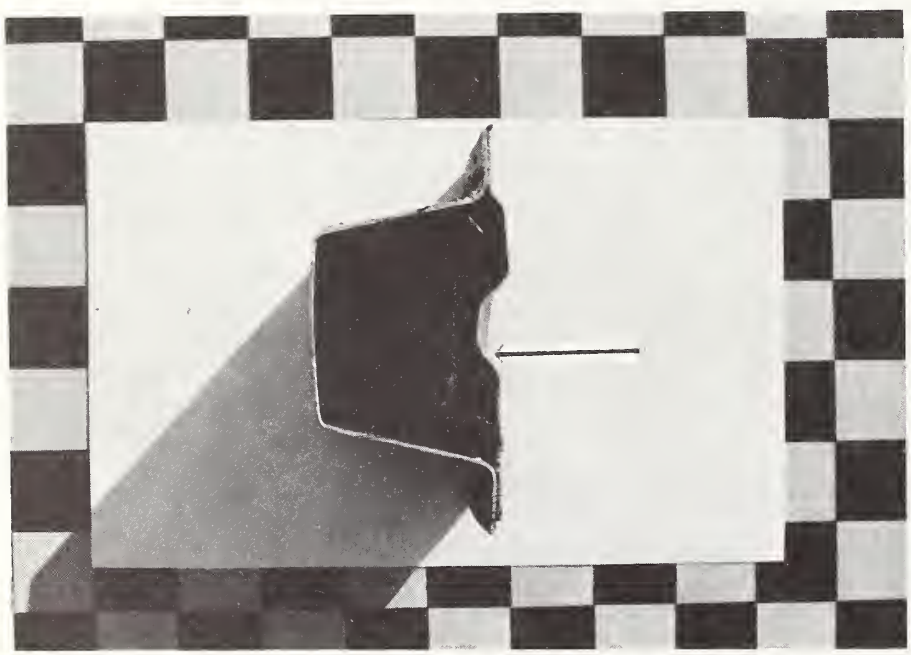

HEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.14, 275.41 28-JUN-84
S66043 S66034 S66043 83270111157 14.8 MPH 14:10:13
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
ACCELERATION (G)
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
TIME (MSEC)
PHOENIX - MIDDLE A-PILLAR


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -25.42, 2225.75
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.08 28-JUN-84
FD42 SAL-66 S66042 832691356S1 17.6 MPH 13:45:58
FORCE (LB)
0.0
300.0
600.0
900.0
1200.0
1500.0
1800.0
2100.0
2400.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISPLACEMENT (IN)
PHOENIX - LOWER A-PILLAR


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -3.36, 1126.57
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.44
FD46 SRL-66 S66046 83276103140 16.9 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
150.0
300.0
450.0
600.0
750.0
900.0
1050.0
1200.0
0.0
0.25
0.5
0.75
1.0
1.25
1.5
1.75
DISPLACEMENT (IN)
PHOENIX - FRONT ROOF RAIL

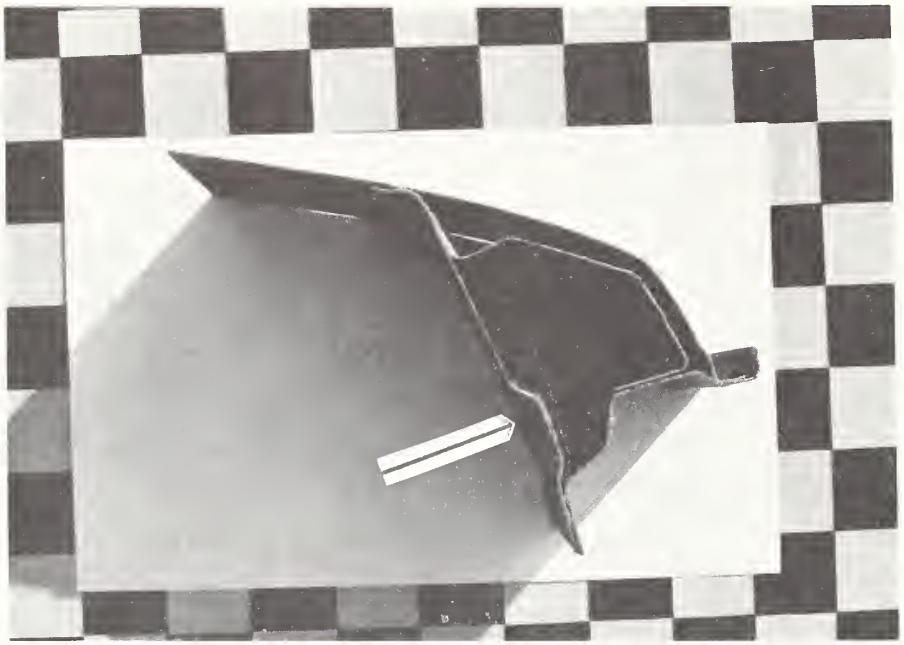

MEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.20, 474.41 28-JUN-84
S66047 S66034 S66047 83276133517 14.7 MPH 14:10:13
480.0
420.0
360.0
300.0
240.0
180.0
120.0
60.0
0.0
ACCELERATION (G)
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
PHOENIX - FRONT ROOF RAIL

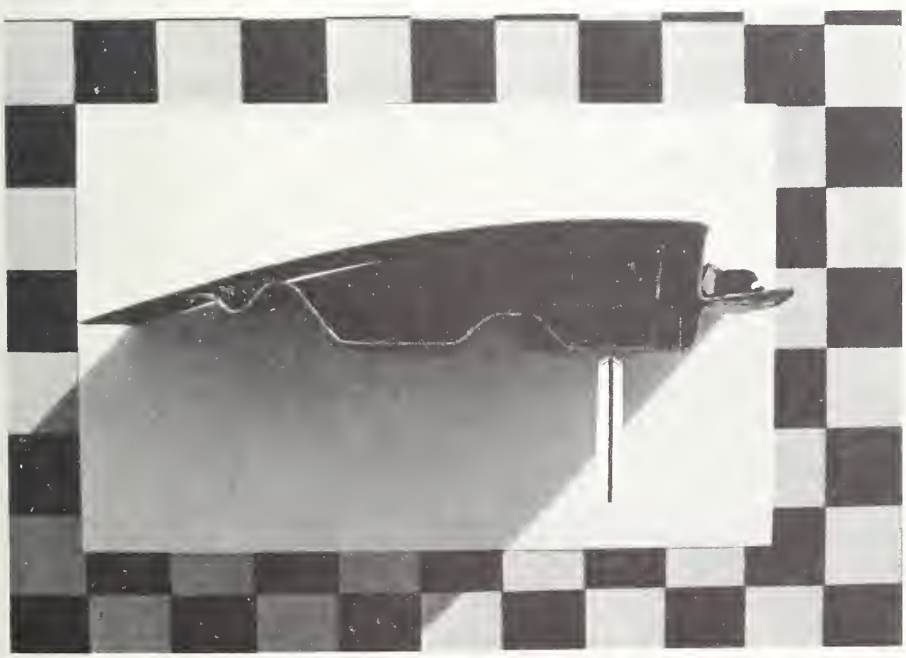
PHOENIX
A-PILLAR



PHOENIX
B-PILLAR

PHOENIX
SIDE ROOF RAIL



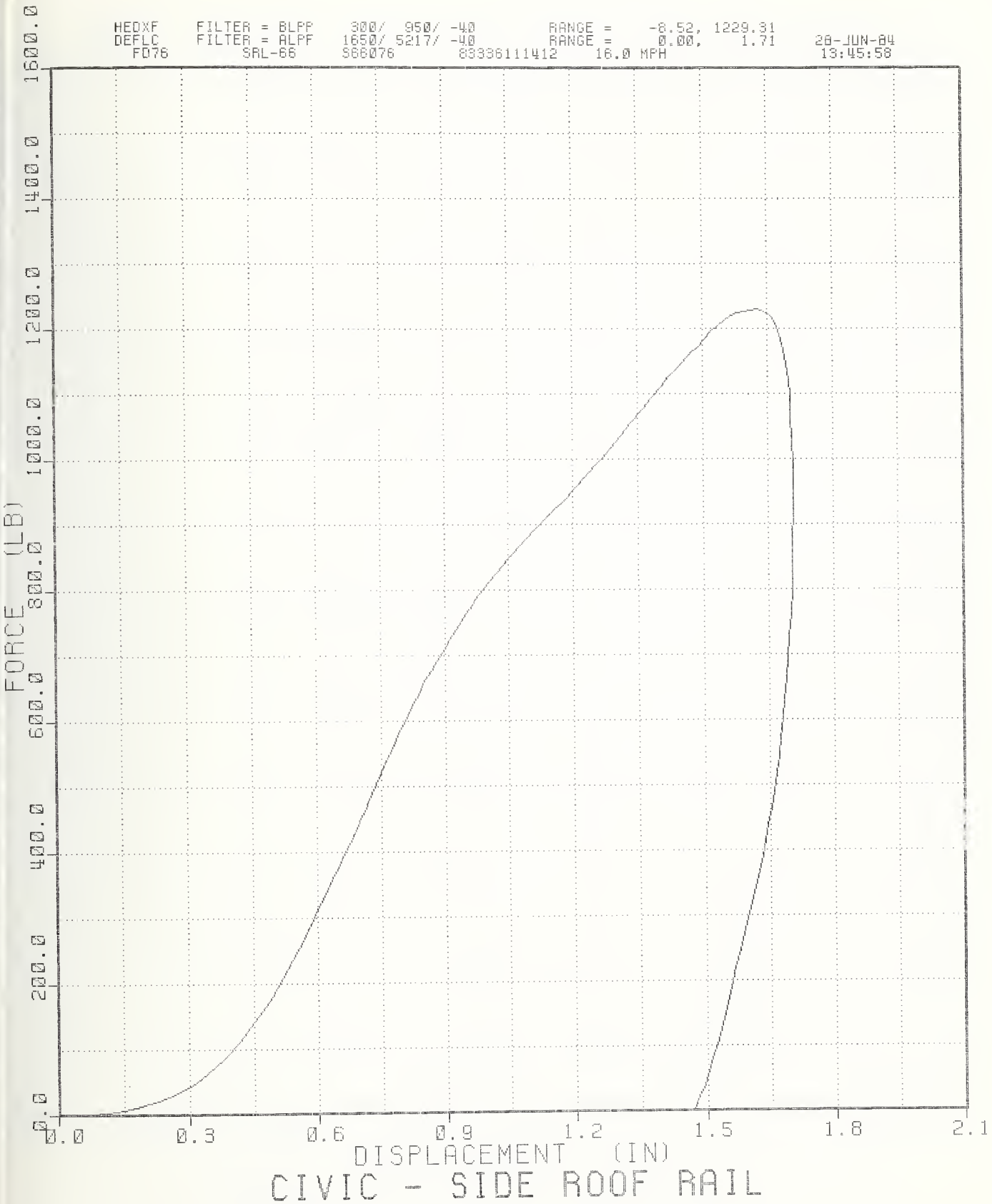


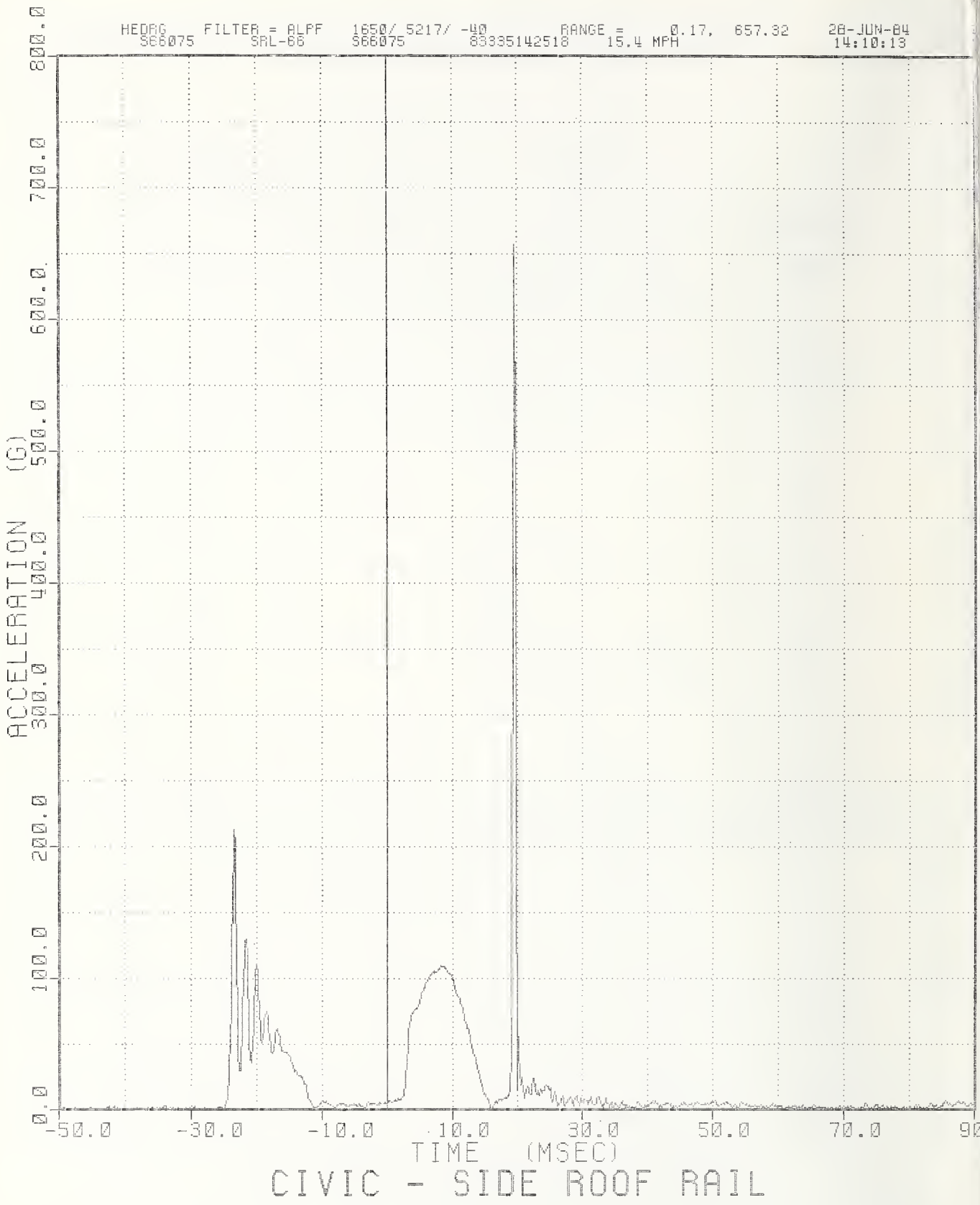
PHOENIX
FRONT ROOF RAIL

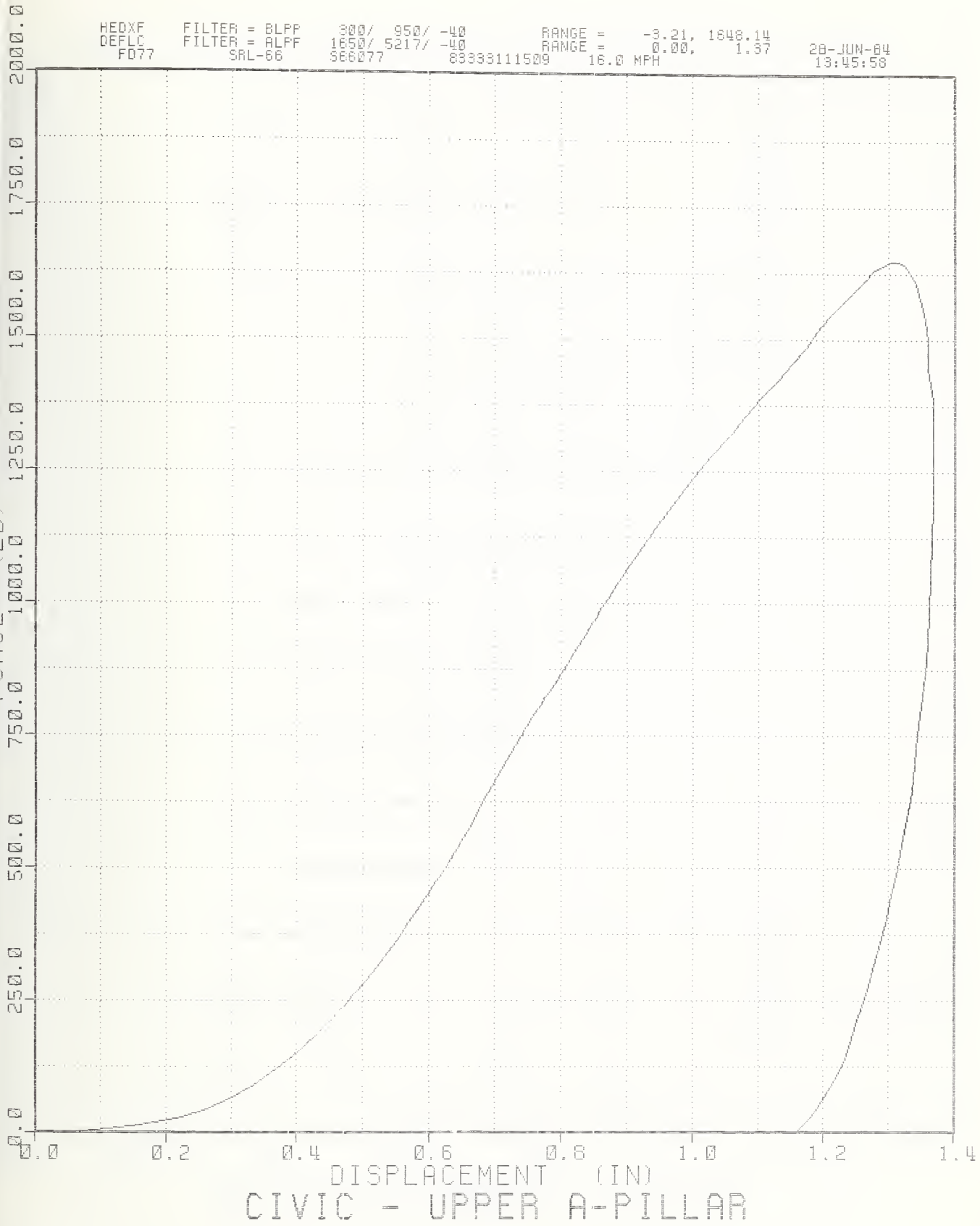
UPPER STRUCTURE MATERIAL AND COVER DATA

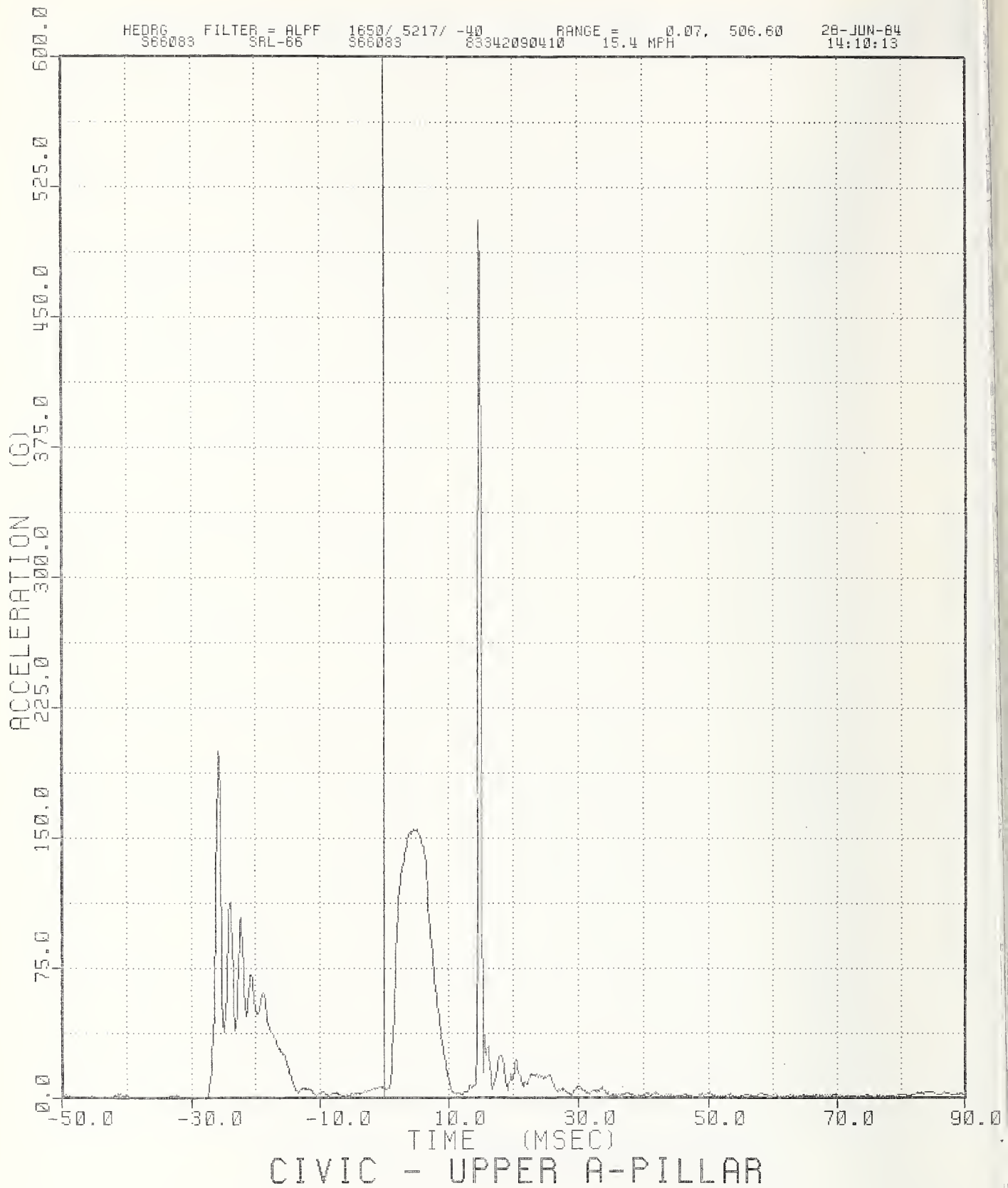
VEHICLE	PHOENIX			
STRUCTURE	SHEET METAL GAGE THICKNESS*	COVER		STRUCTURE LENGTH
		TYPE OF MATERIAL	GAGE THICKNESS	
A-PILLAR	0.050"	brittle plastic	0.092"	23 3/4"
SIDE ROOF RAIL	0.033"	brittle plastic	0.092"	19"
FRONT ROOF RAIL	0.033"	cloth/ cardboard & aluminum strip	0.031" (aluminum)	
B-PILLAR	0.033"	mild plastic	0.092"	

* If more than one gage thickness is listed, the first is that of the impacted surface.

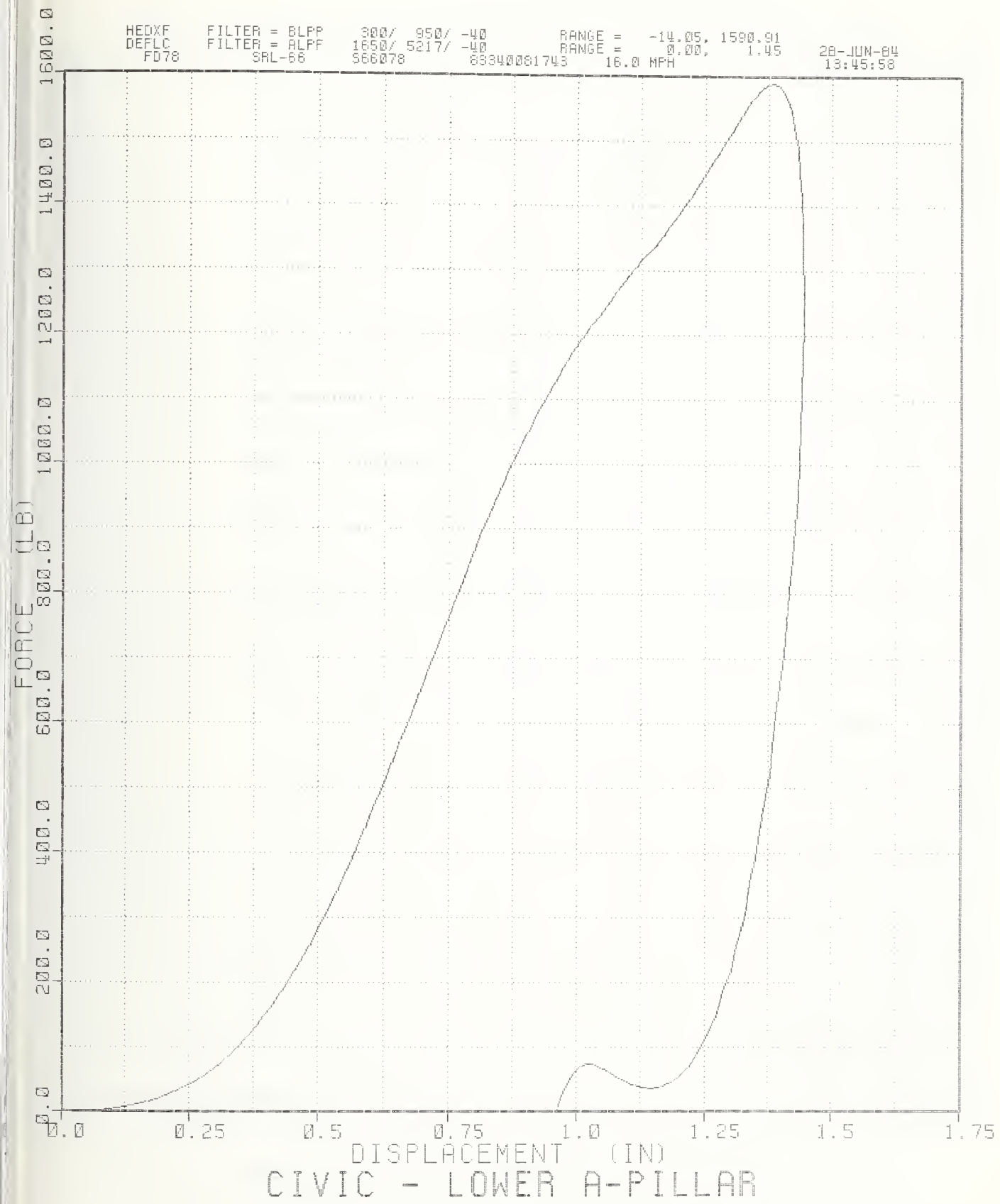

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -8.52, 1229.31
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.71 28-JUN-84
F076 SRL-66 S66076 83336111412 16.0 MPH 13:45:58
FORCE (LB)
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
DISPLACEMENT (IN)
CIVIC - SIDE ROOF RAIL


HEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.17, 657.32 28-JUN-84
S66075 SRL-66 S66075 83335142518 15.4 MPH 14:10:13
ACCELERATION (G)
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
TIME (MSEC)
CIVIC - SIDE ROOF RAIL

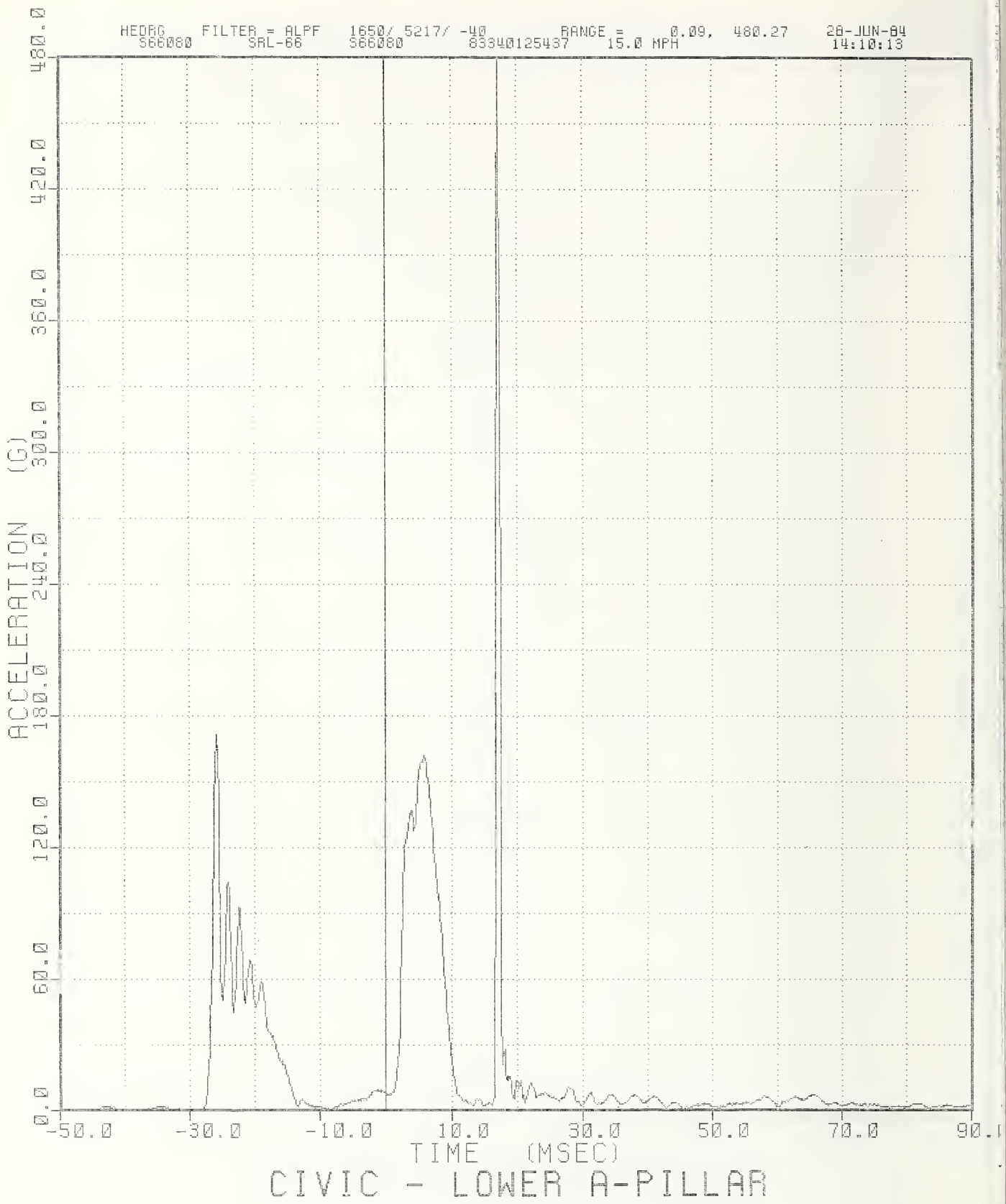

HEDXF FILTER = BLPF 300/ 950/ -40 RANGE = -3.21, 1648.14
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.37
FD77 SRL-66 S66077 83383111509 16.0 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISPLACEMENT (IN)
CIVIC - UPPER A-PILLAR

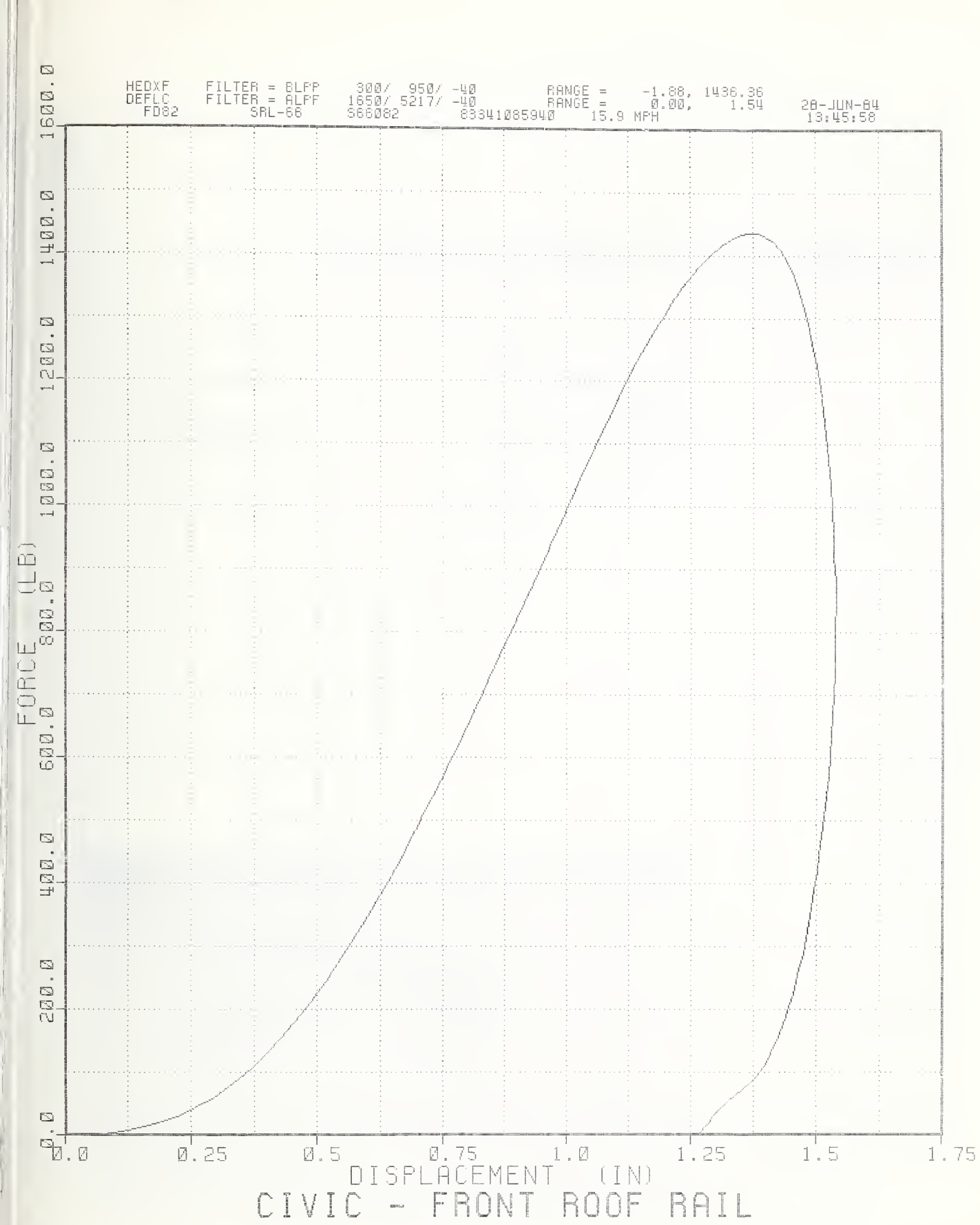


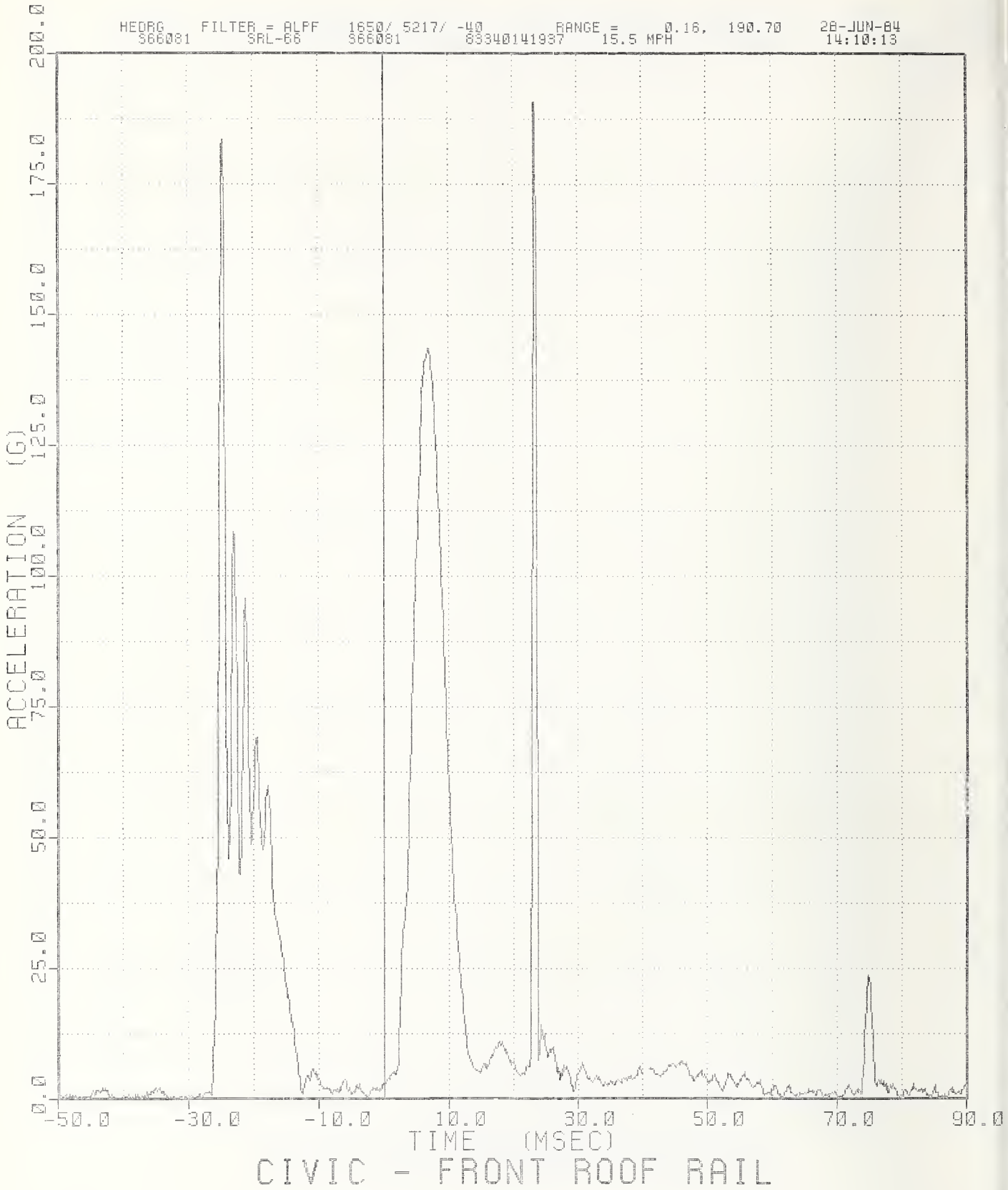
CIVIC - UPPER A-PILLAR



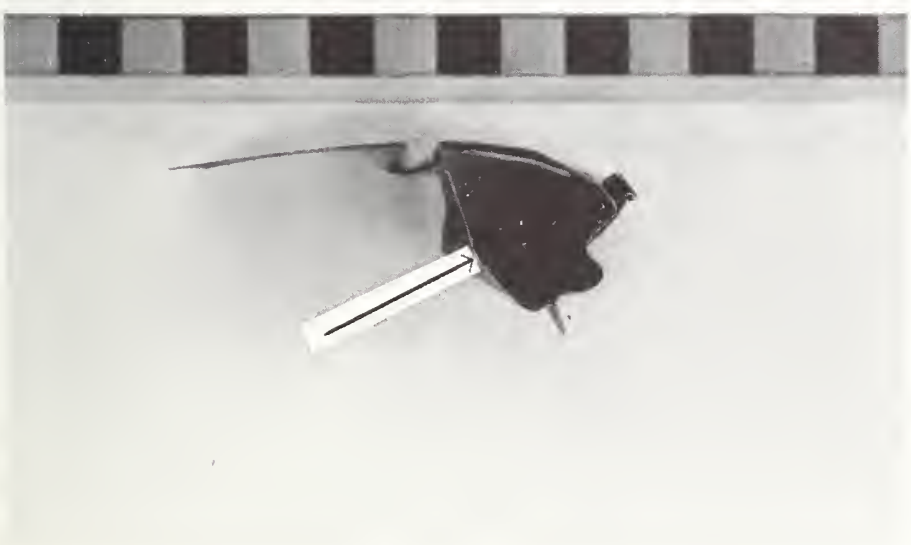
CIVIC - LOWER A-PILLAR


HEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.09, 480.27 28-JUN-84
S66080 SRL-66 S66080 83340125437 15.0 MPH 14:10:13
480.0
420.0
360.0
300.0
240.0
180.0
120.0
60.0
0.0
ACCELERATION (G)
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
CIVIC - LOWER A-PILLAR


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -1.88, 1436.36
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.54 28-JUN-84
FD82 SRL-66 S66082 83341085940 15.9 MPH 13:45:58
FORCE (LB)
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
0.0
0.25
0.5
0.75
1.0
1.25
1.5
1.75
DISPLACEMENT (IN)
CIVIC - FRONT ROOF RAIL


HEORG FILTER = ALFF 1650/ 5217/ -40 RANGE = 0.16, 190.70 28-JUN-84
366081 SRL-66 366081 83340141937 15.5 MPH 14:10:13
ACCELERATION (G)
200.0
175.0
150.0
125.0
100.0
75.0
50.0
25.0
0.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
CIVIC - FRONT ROOF RAIL

CIVIC
A-PILLAR



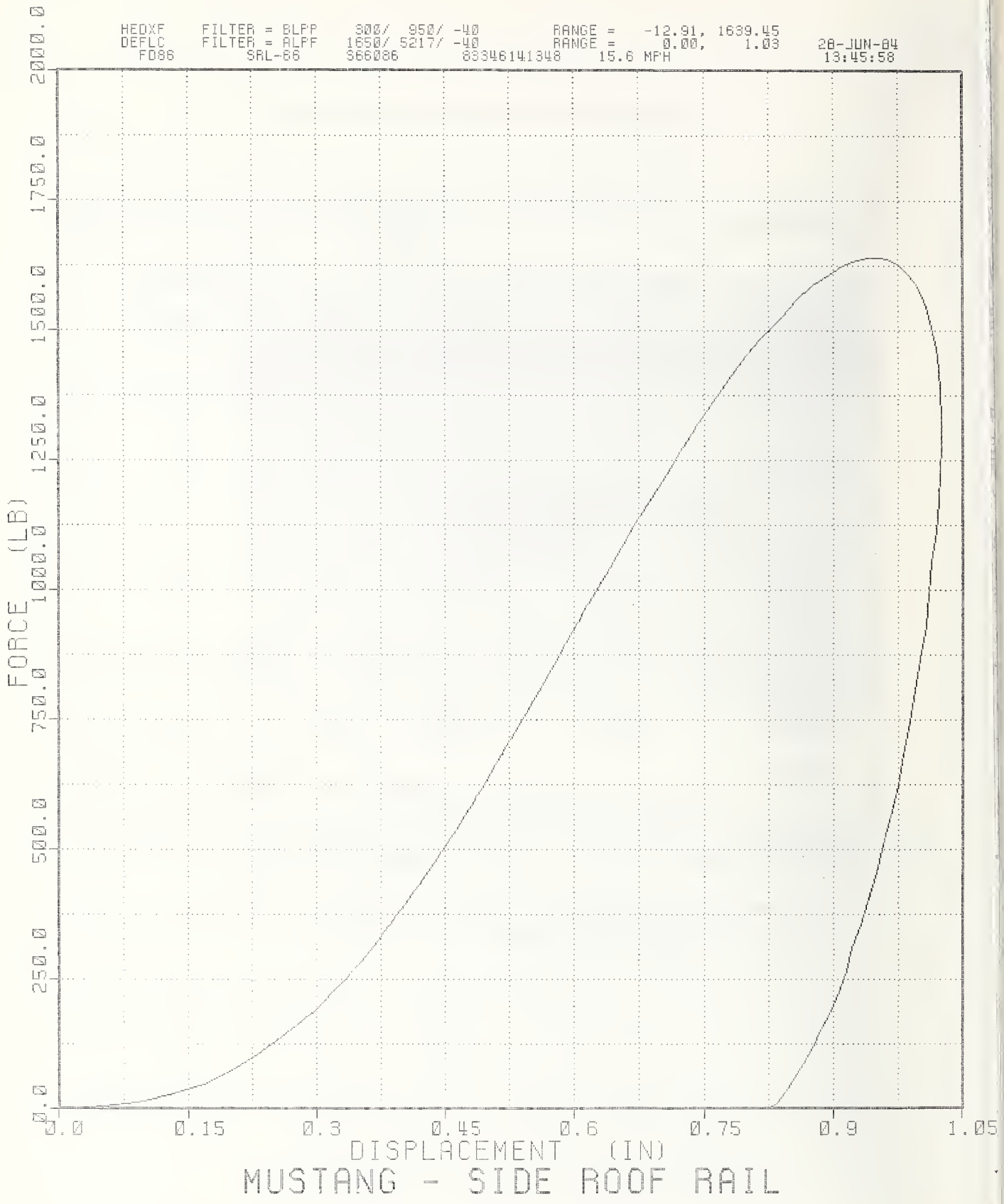
CIVIC
SIDE ROOF RAIL

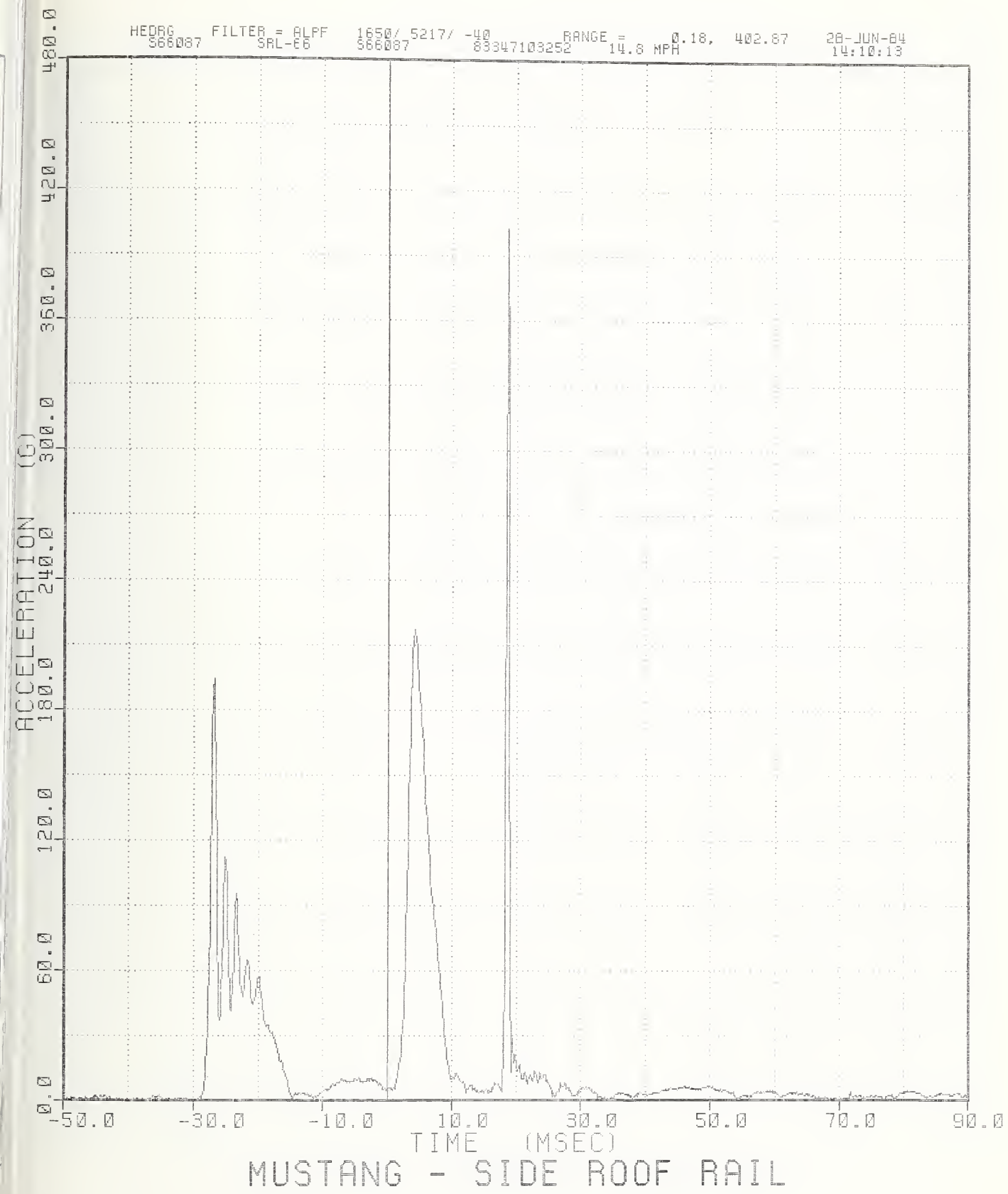
CIVIC FRONT ROOF RAIL

UPPER STRUCTURE MATERIAL AND COVER DATA

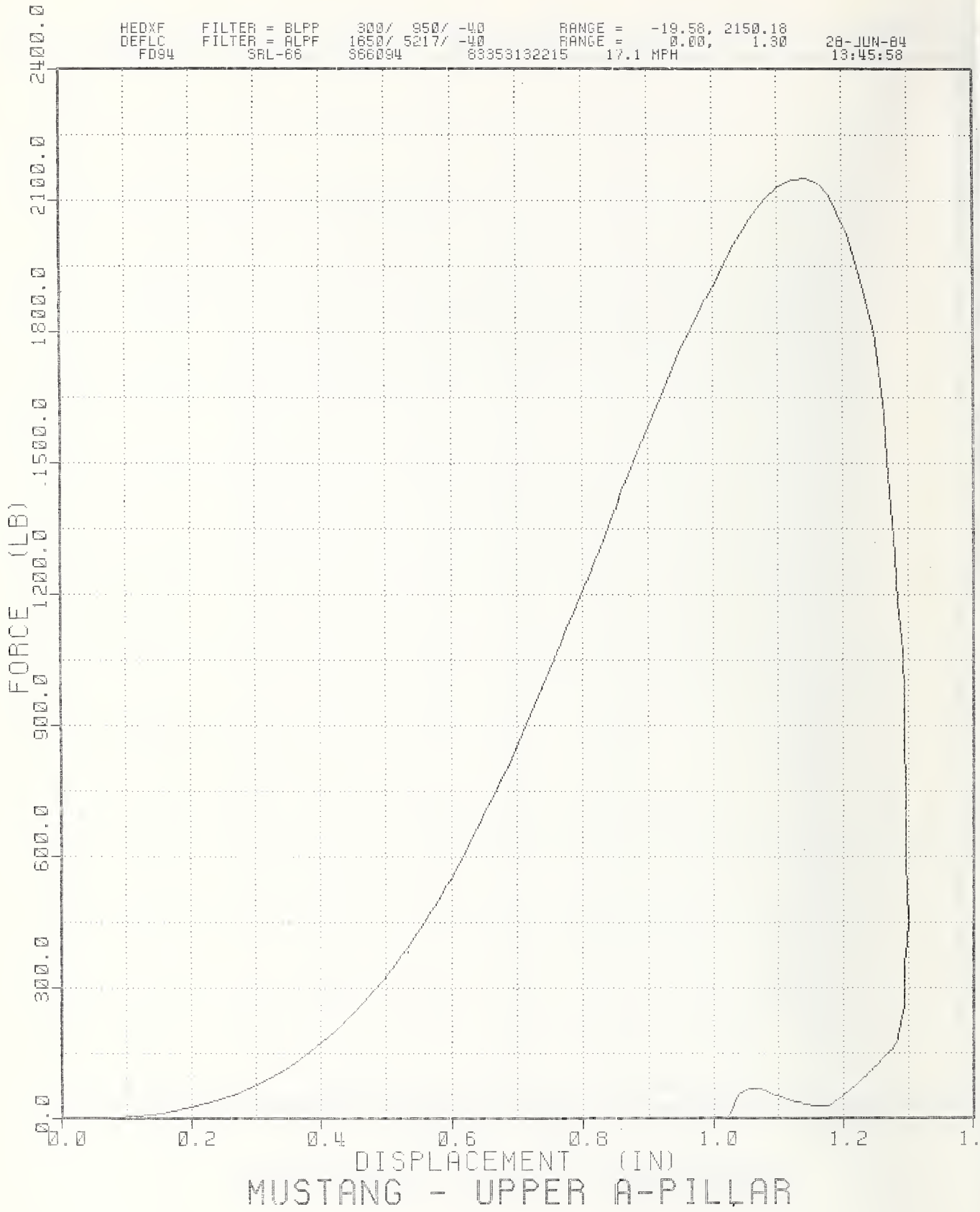
VEHICLE	CIVIC			
STRUCTURE	SHEET METAL GAGE THICKNESS*	COVER		STRUCTURE LENGTH
		TYPE OF MATERIAL	GAGE THICKNESS	
A-PILLAR	0.042" & 0.028"	hard/not brittle plastic	0.081"	21"
SIDE ROOF RAIL	0.028"	vinyl cloth		24"
FRONT ROOF RAIL	0.028"	vinyl cloth		
B-PILLAR				

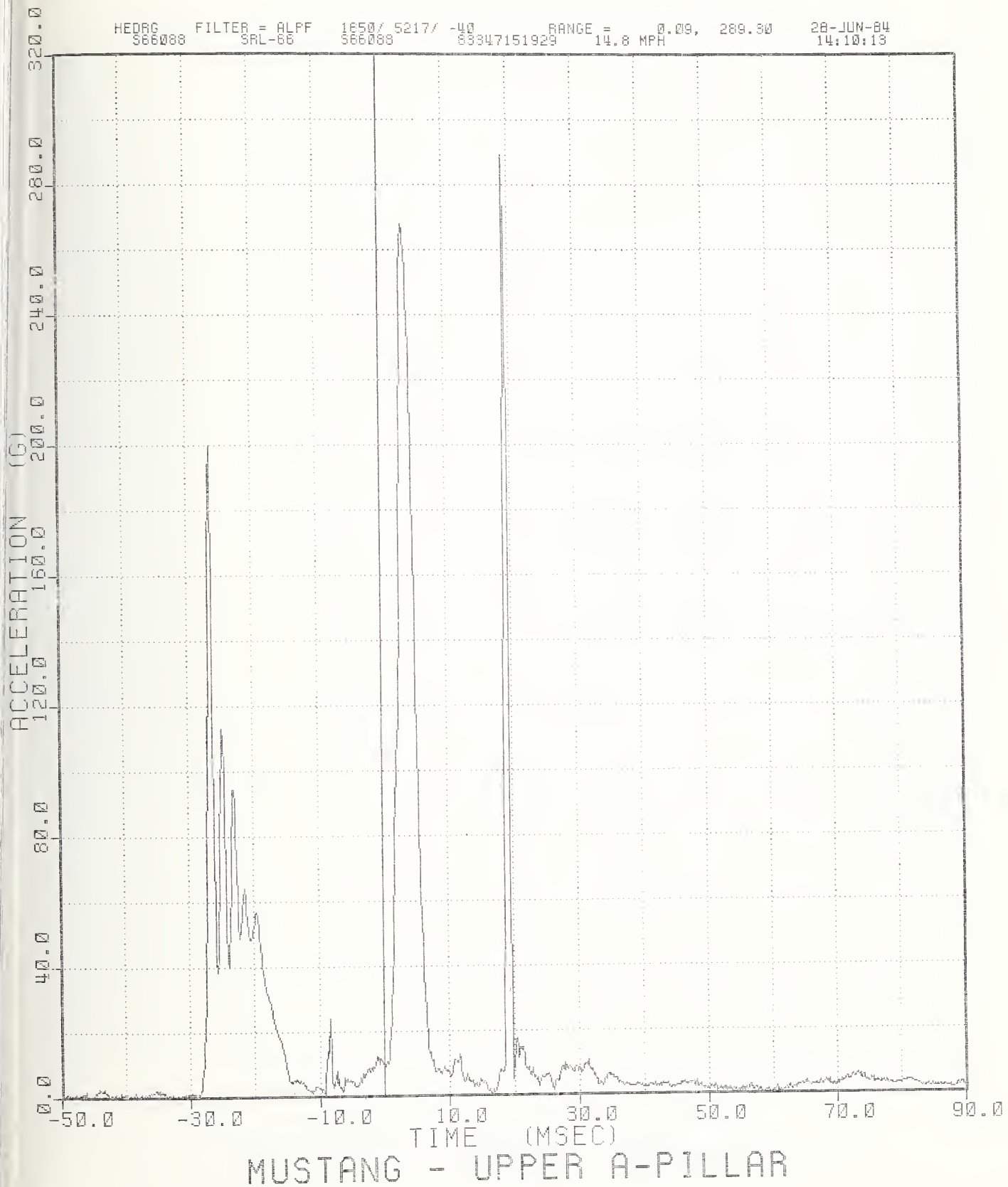
* If more than one gage thickness is listed, the first is that of the impacted surface.


HEDXF FILTER = BLPF 300/ 950/ -40 RANGE = -12.91, 1639.45
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.03
FD86 SAL-86 S66086 88346141348 15.6 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
0.0
0.15
0.3
0.45
0.6
0.75
0.9
1.05
DISPLACEMENT (IN)
MUSTANG - SIDE ROOF RAIL

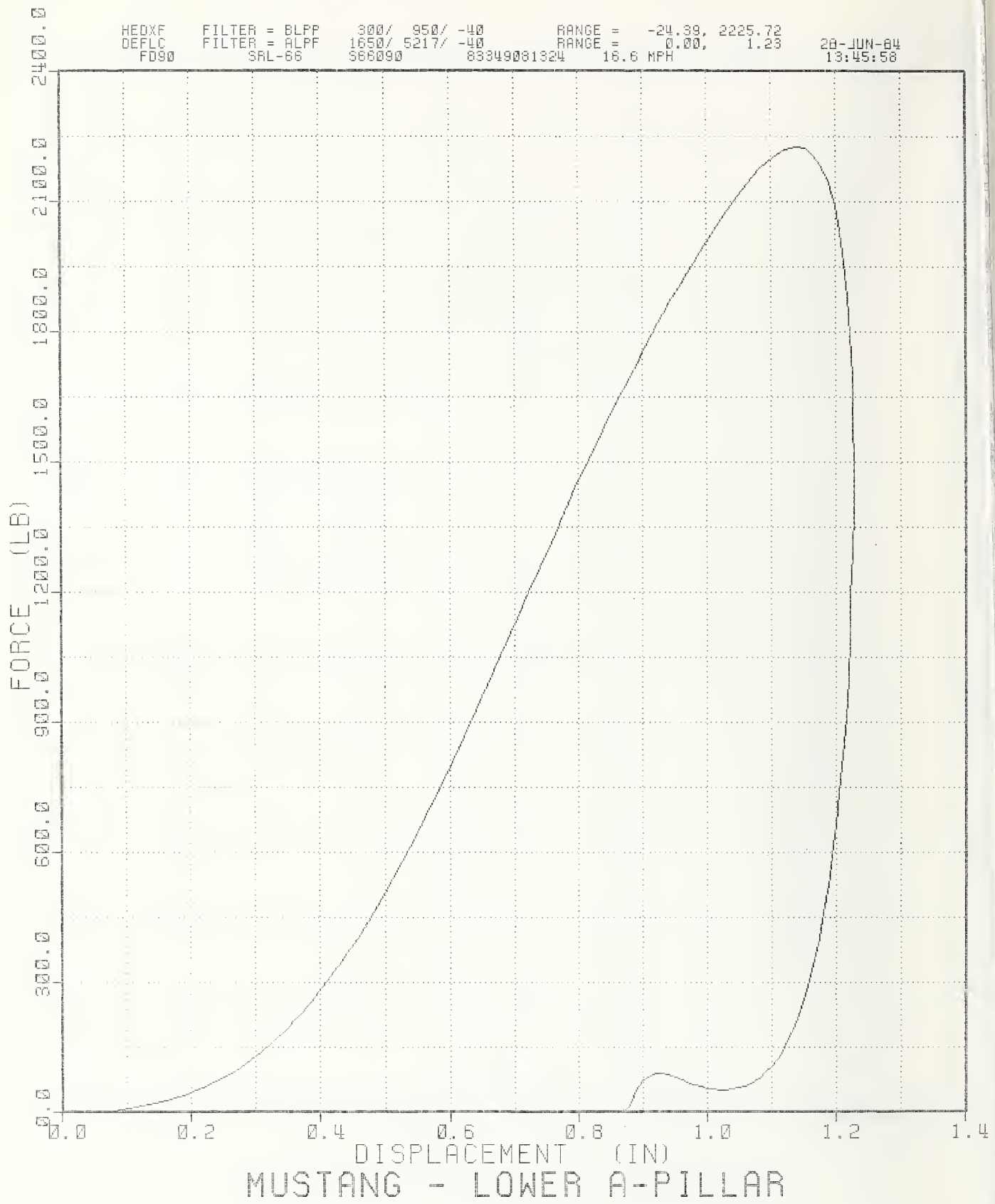


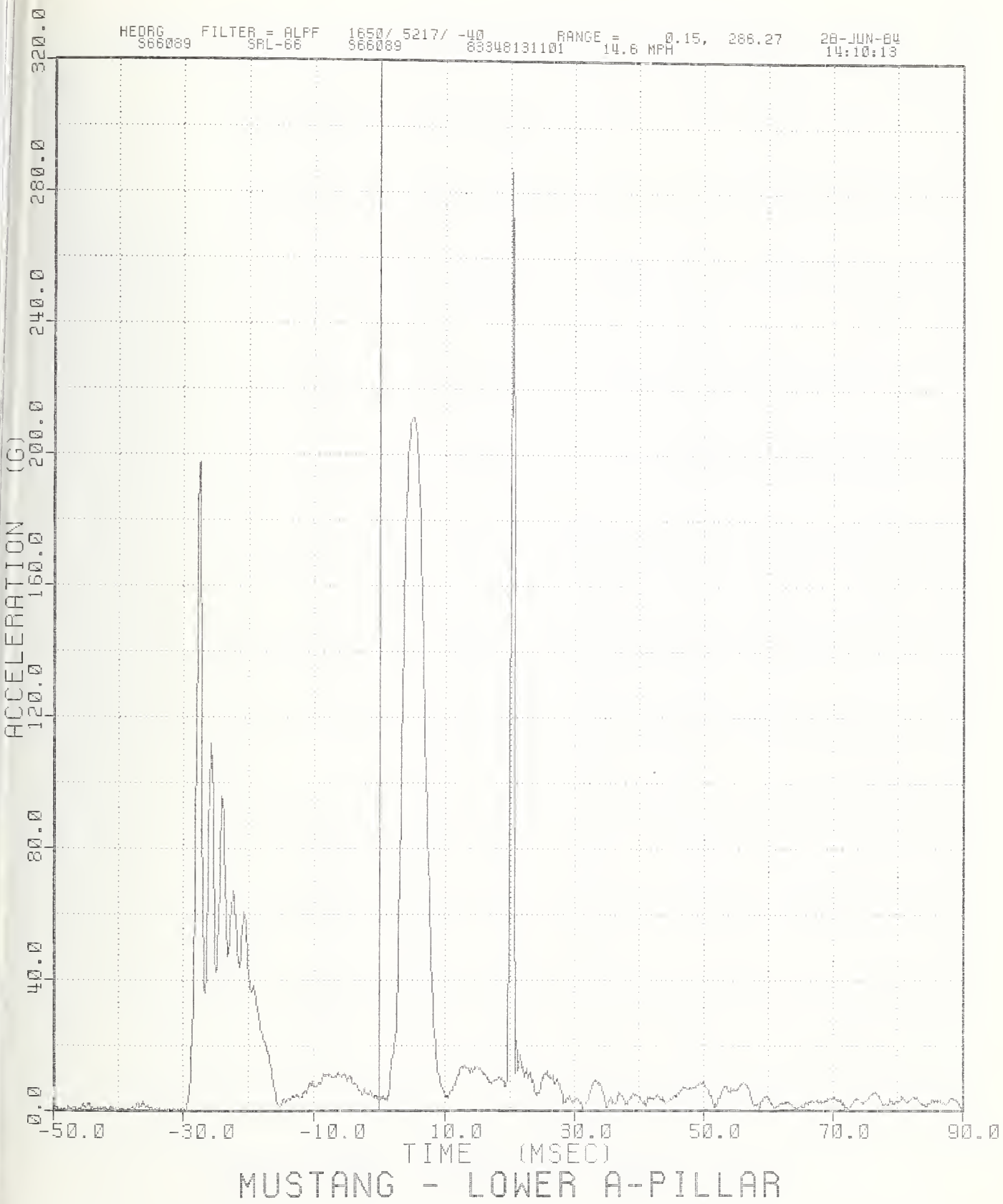
MUSTANG - SIDE ROOF RAIL

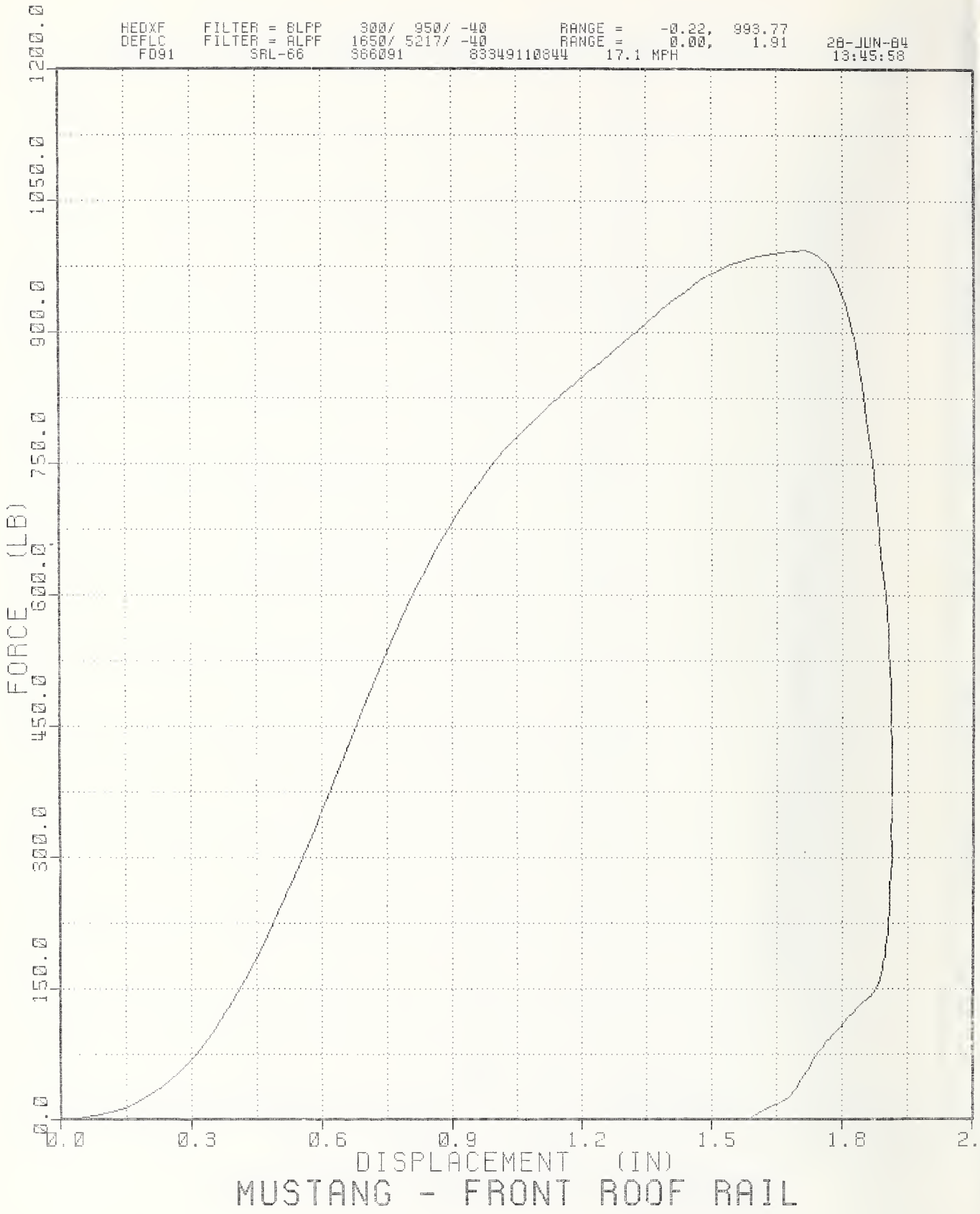

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -19.58, 2150.18
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.30 28-JUN-84
FD94 SRL-66 S66094 83353132215 17.1 MPH 13:45:58
FORCE (LB)
2400.0
2100.0
1800.0
1500.0
1200.0
900.0
600.0
300.0
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISPLACEMENT (IN)
MUSTANG - UPPER A-PILLAR

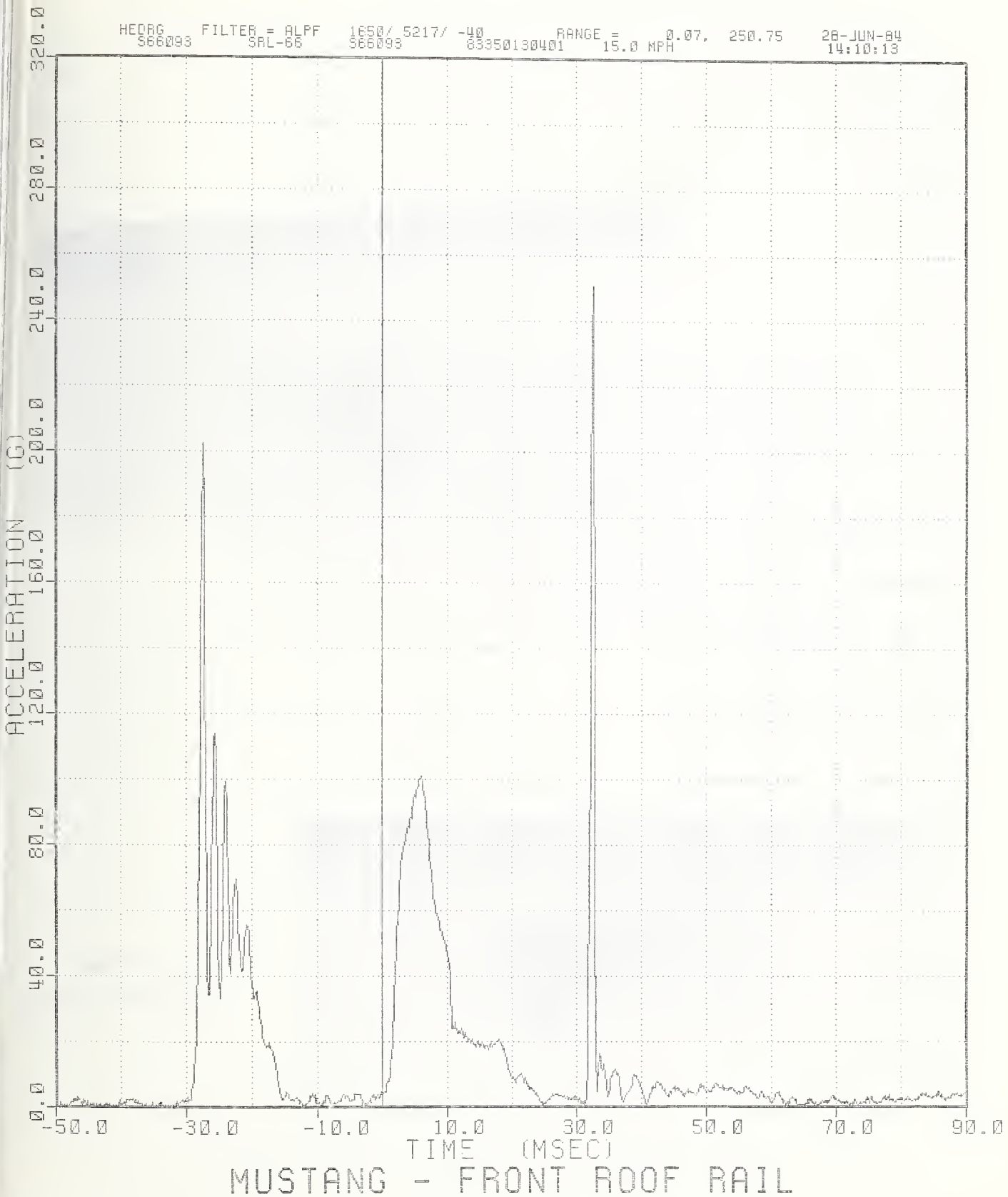


MUSTANG - UPPER A-PILLAR


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -24.39, 2225.72
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.23
FD90 SRL-66 866090 83349081324 16.6 MPH
28-JUN-84
13:45:58
FORCE (LB)
2400.0
2100.0
1800.0
1500.0
1200.0
900.0
600.0
300.0
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISPLACEMENT (IN)
MUSTANG - LOWER A-PILLAR


HEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.15, 286.27 28-JUN-84
S66089 SRL-66 S66089 83348131101 14.6 MPH 14:10:13
ACCELERATION (G)
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
MUSTANG - LOWER A-PILLAR


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -0.22, 993.77
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.91
FD91 SRL-66 866091 83349110844 17.1 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
150.0
300.0
450.0
600.0
750.0
900.0
1050.0
1200.0
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
DISPLACEMENT (IN)
MUSTANG - FRONT ROOF RAIL


HEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.07, 250.75 28-JUN-84
S66093 SRL-66 S66093 83350130401 15.0 MPH 14:10:13
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
ACCELERATION (G)
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
MUSTANG - FRONT ROOF RAIL

MUSTANG
A-PILLAR

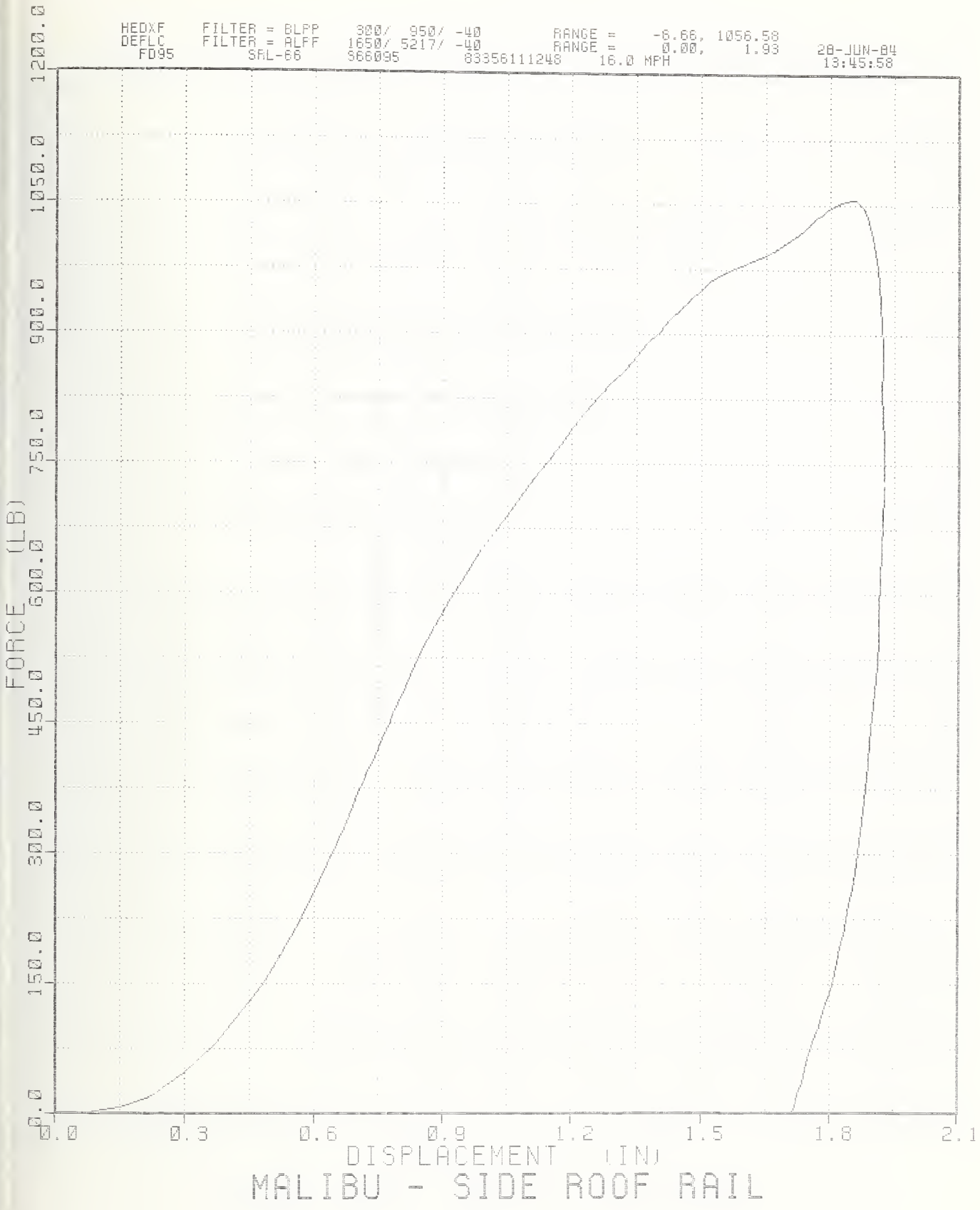
MUSTANG
SIDE ROOF RAIL

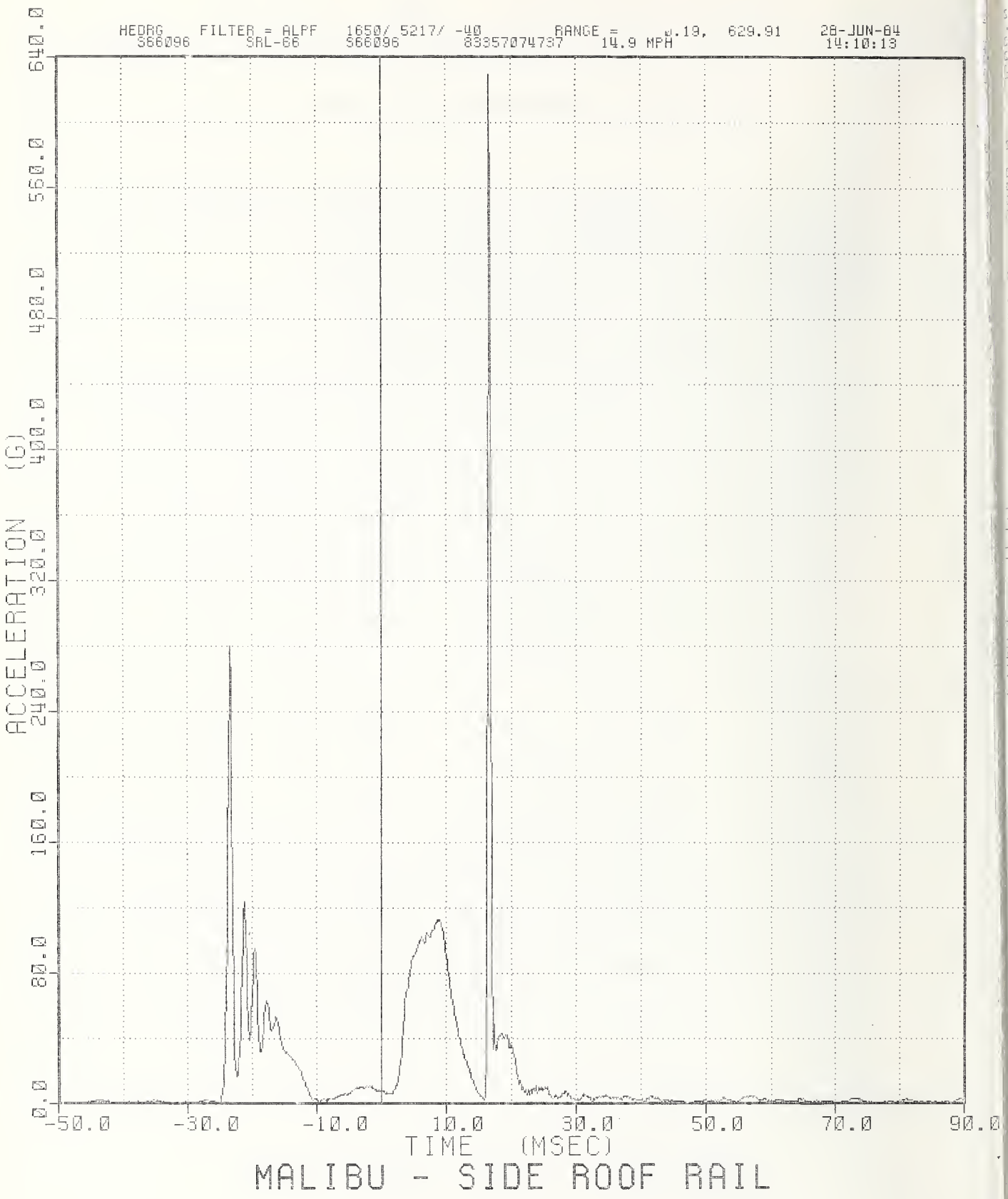
MUSTANG FRONT ROOF RAIL

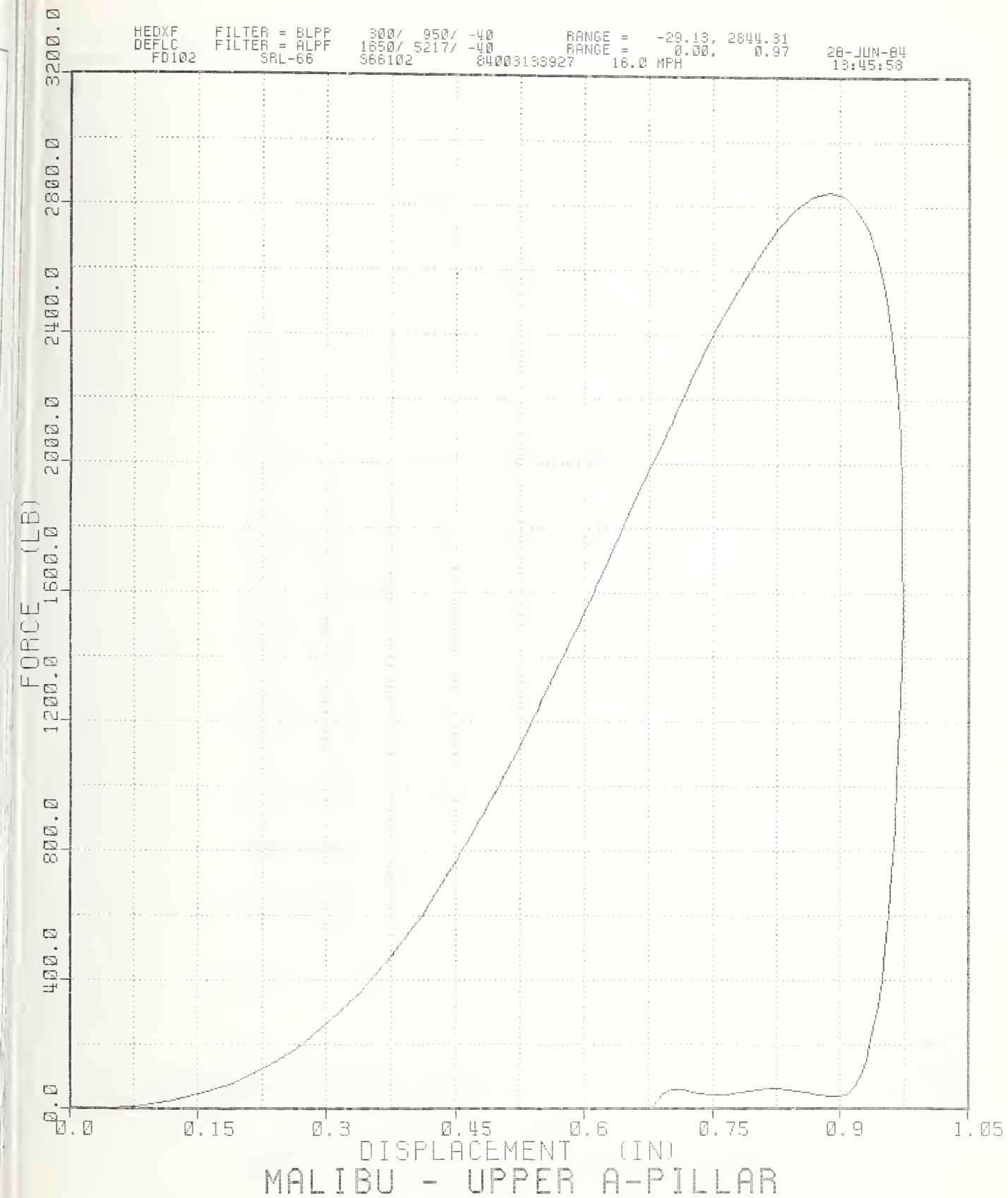
UPPER STRUCTURE MATERIAL AND COVER DATA

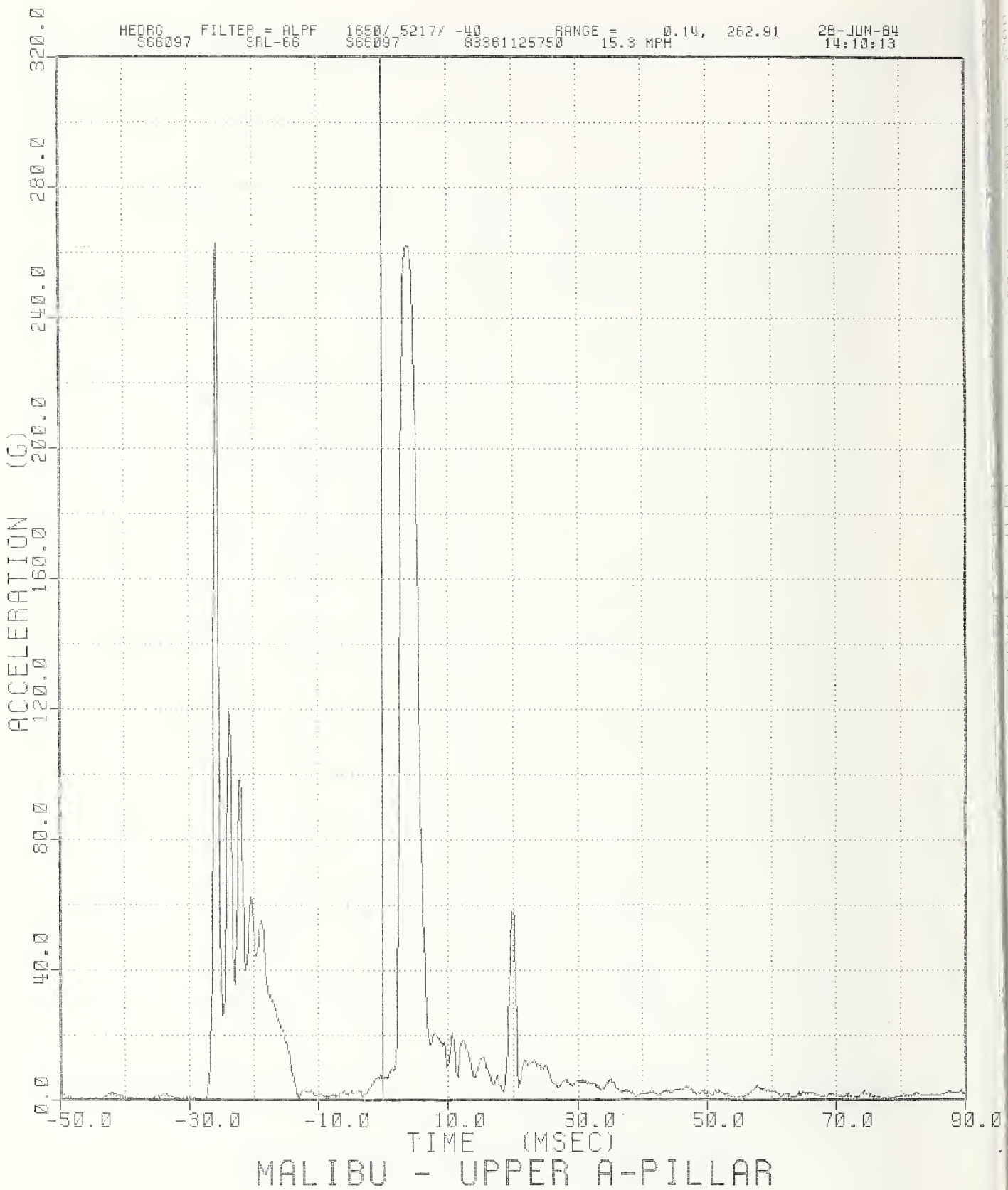
VEHICLE	MUSTANG			
STRUCTURE	SHEET METAL GAGE THICKNESS*	COVER		STRUCTURE LENGTH
		TYPE OF MATERIAL	GAGE THICKNESS	
A-PILLAR	0.060" & 0.050"	brittle plastic	0.105"	22 1/2"
SIDE ROOF RAIL	0.035" & 0.050" & 0.029"	cloth/ cardboard & aluminum strip	1/8" & 0.028"	25"
FRONT ROOF RAIL	0.035" & 0.029"	cloth/ cardboard & aluminum strip	1/8" & 0.042"	
B-PILLAR				

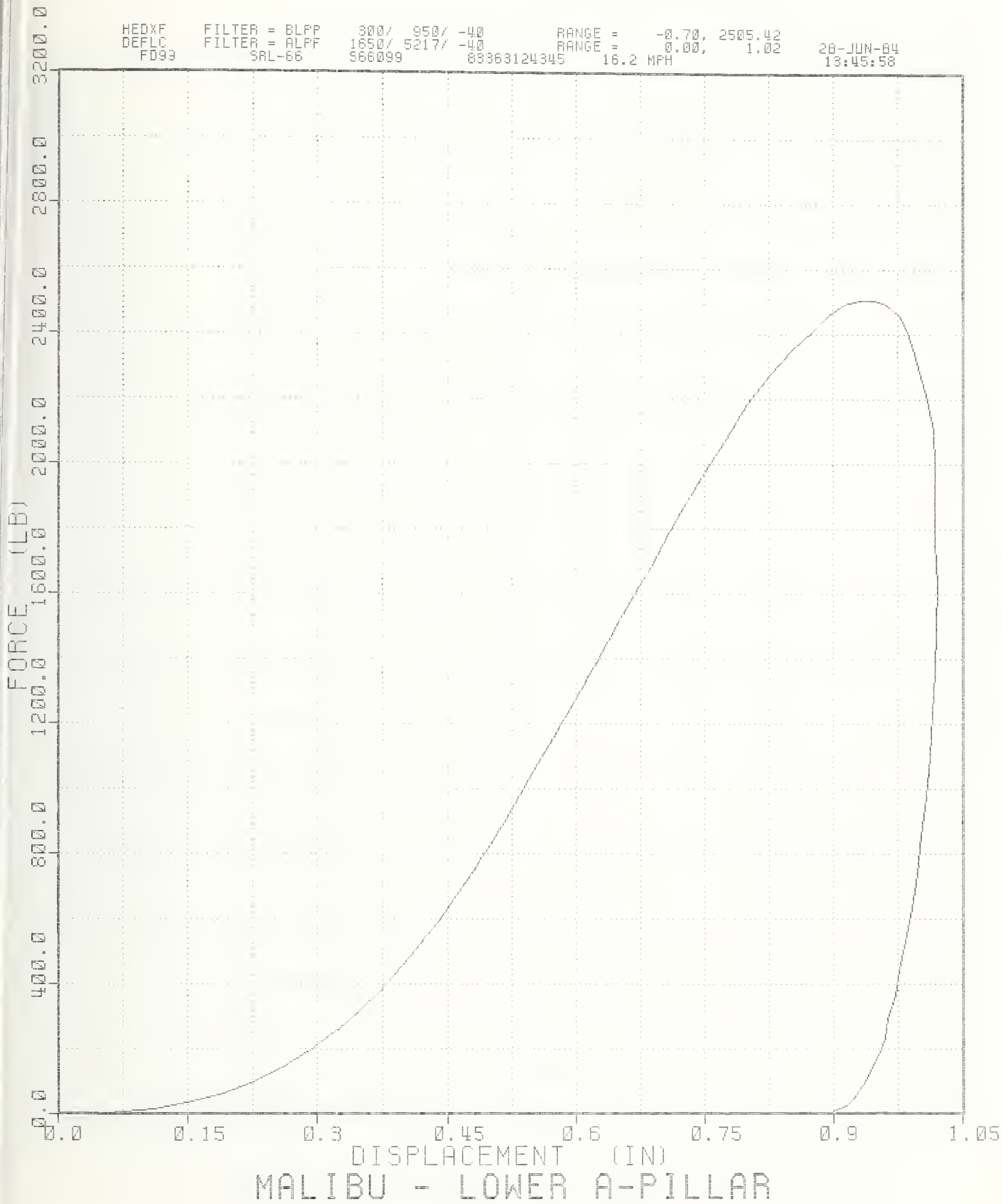
* If more than one gage thickness is listed, the first is that of the impacted surface.

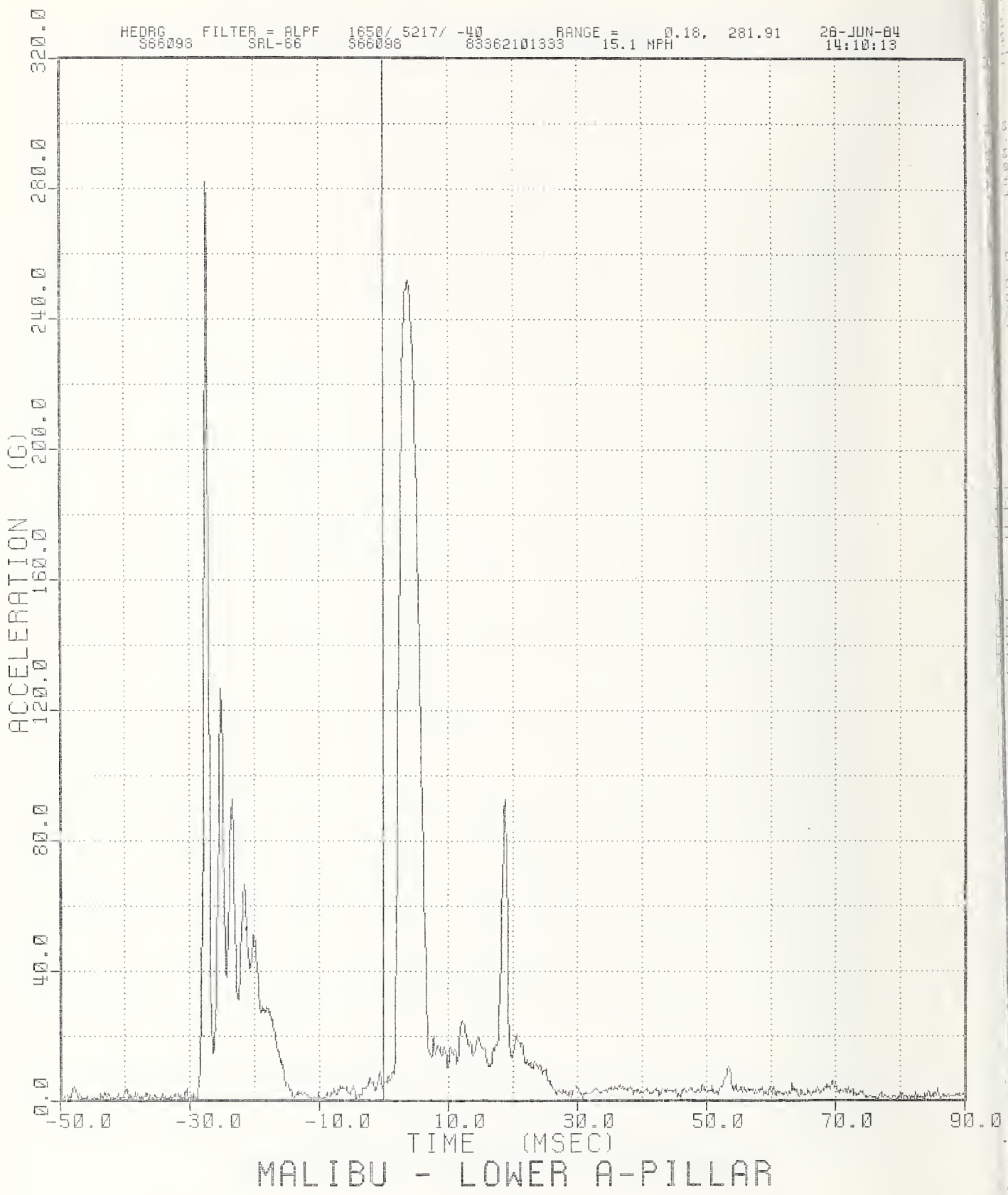

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -6.66, 1056.58
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.93
FD95 SRL-66 566095 83356111248 16.0 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
150.0
300.0
450.0
600.0
750.0
900.0
1050.0
1200.0
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
DISPLACEMENT (IN)
MALIBU - SIDE ROOF RAIL

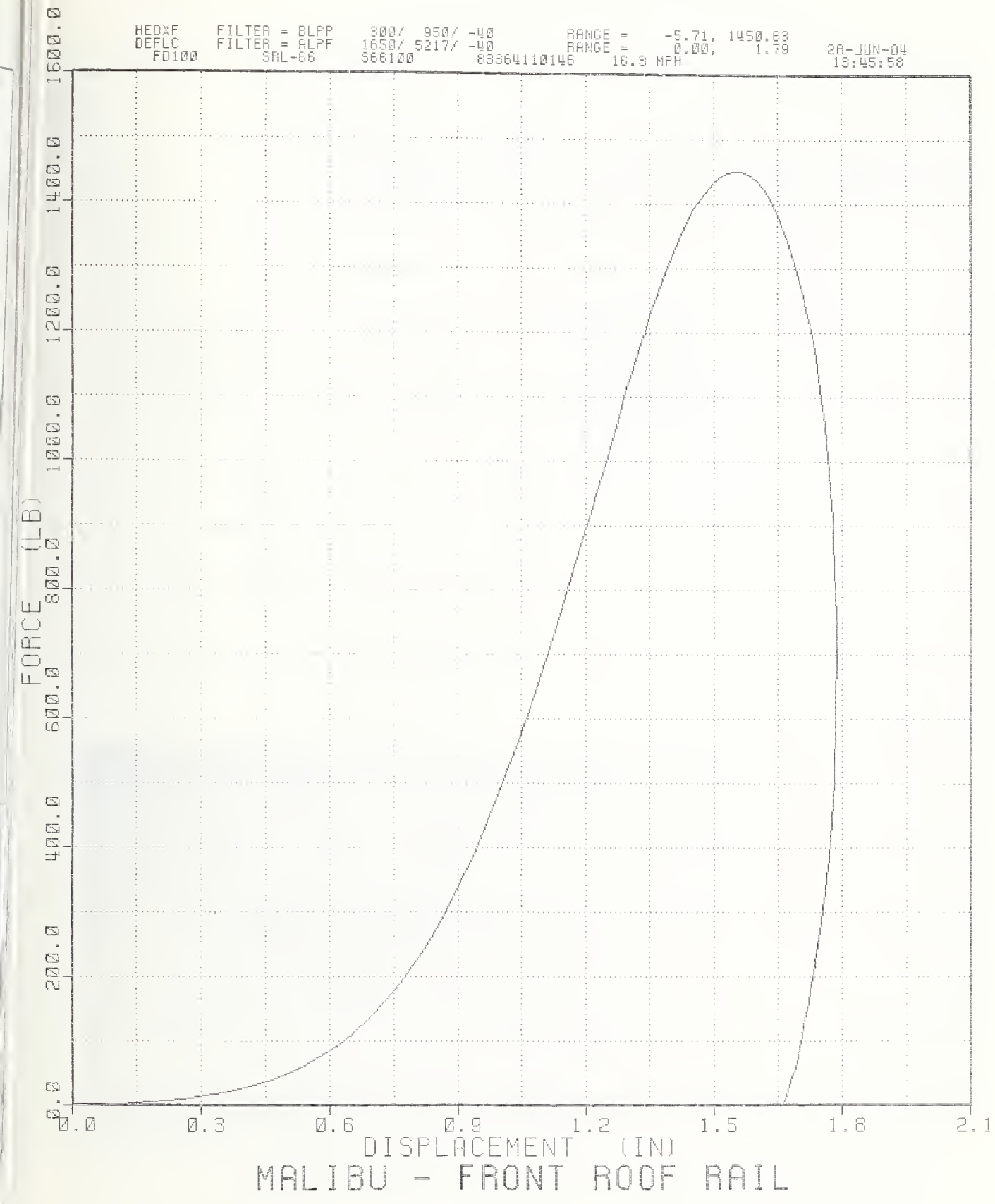

HEDRG S66096
FILTER = ALPF
SAL-66
1650/ 5217/ -40
S66096
83357074737
RANGE = 14.9 MPH
0.19, 629.91
28-JUN-84
14:10:13
ACCELERATION (G)
0.0
80.0
160.0
240.0
320.0
400.0
480.0
560.0
640.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
MALIBU - SIDE ROOF RAIL

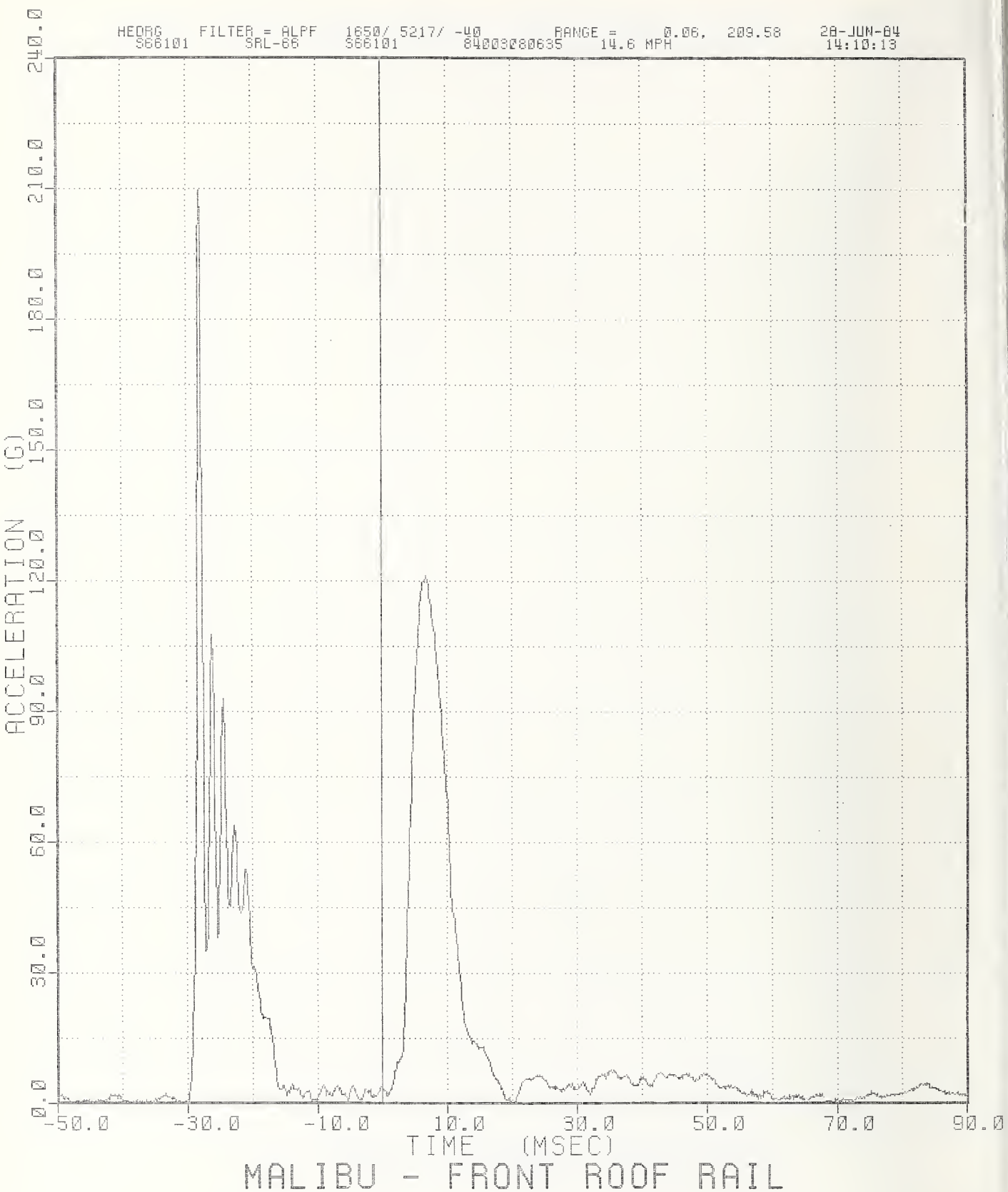

HEDXF FILTER = BLPF 300/ 950/ -40 RANGE = -29.13, 2844.31
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 0.97 28-JUN-84
FD102 SRL-66 S66102 84003133927 16.0 MPH 13:45:58
FORCE (LB)
3200.0
2800.0
2400.0
2000.0
1600.0
1200.0
800.0
400.0
0.0
0.0
0.15
0.3
0.45
0.6
0.75
0.9
1.05
DISPLACEMENT (IN)
MALIBU - UPPER A-PILLAR


HEDRG S66097
FILTER = ALPF SRL-66
1650/ 5217/ -40 S66097
83361125750
RANGE = 0.14, 262.91
15.3 MPH
28-JUN-84
14:10:13
ACCELERATION (G)
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
MALIBU - UPPER A-PILLAR

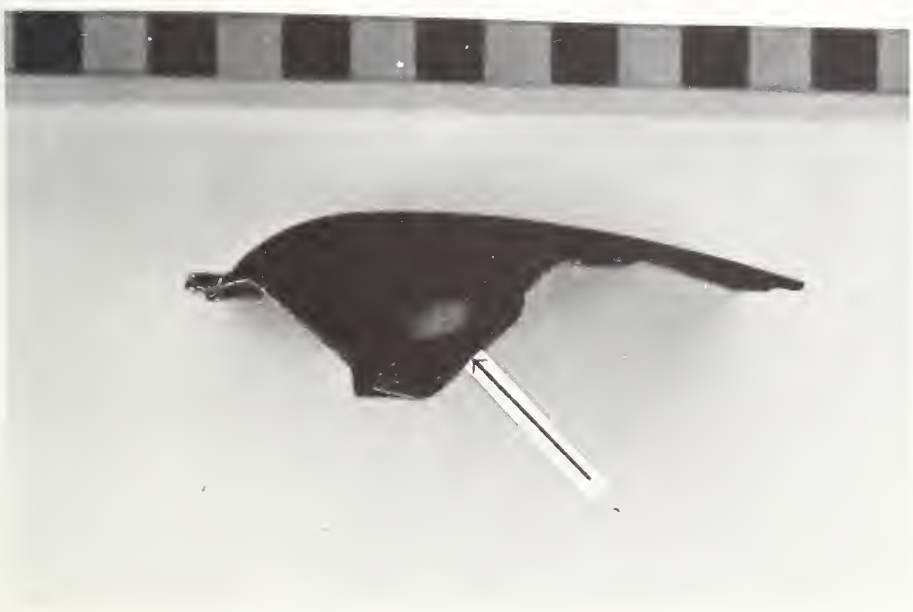

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -0.70, 2505.42
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.02
FD99 SRL-66 S66099 83363124345 16.2 MPH
28-JUN-84
13:45:58
FORCE (LBS)
3200.0
2800.0
2400.0
2000.0
1600.0
1200.0
800.0
400.0
0.0
0.0
0.15
0.3
0.45
0.6
0.75
0.9
1.05
DISPLACEMENT (IN)
MALIBU - LOWER A-PILLAR


HEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.18, 281.91 26-JUN-84
S66098 SRL-66 S66098 83362101333 15.1 MPH 14:10:13
ACCELERATION (G)
320.0
280.0
240.0
200.0
160.0
120.0
80.0
40.0
0.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
MALIBU - LOWER A-PILLAR


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -5.71, 1450.63
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.79 28-JUN-84
FD100 SRL-66 S66100 83364110146 16.3 MPH 13:45:58
FORCE (LB)
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
DISPLACEMENT (IN)
MALIBU - FRONT ROOF RAIL


HEDRG FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.06, 209.58 28-JUN-84
S66101 SRL-66 S66101 84003080635 14.6 MPH 14:10:13
ACCELERATION (G)
240.0
210.0
180.0
150.0
120.0
90.0
60.0
30.0
0.0
-50.0
-30.0
-10.0
10.0
30.0
50.0
70.0
90.0
TIME (MSEC)
MALIBU - FRONT ROOF RAIL

MALIBU
A-PILLAR



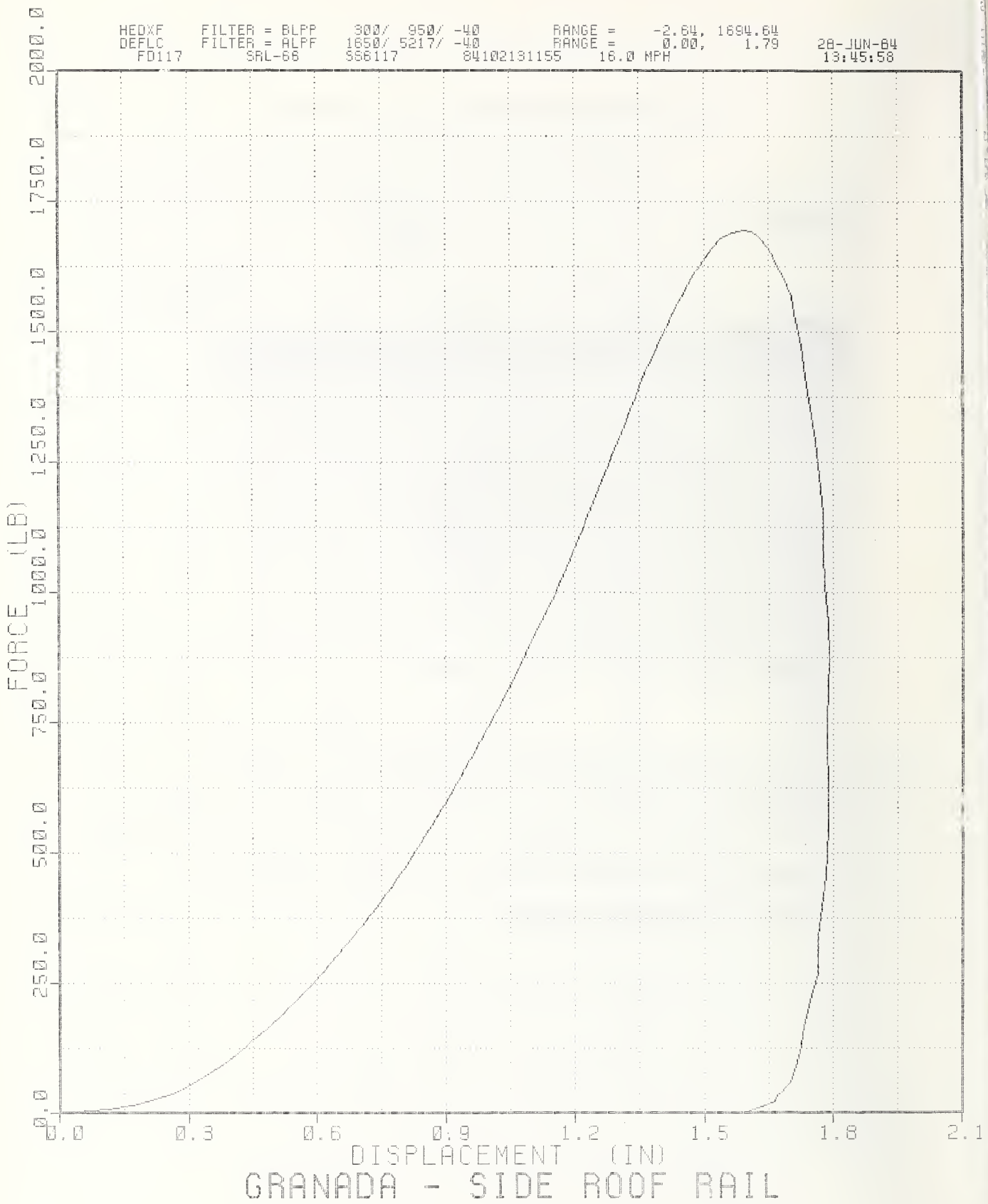
MALIBU
SIDE ROOF RAIL

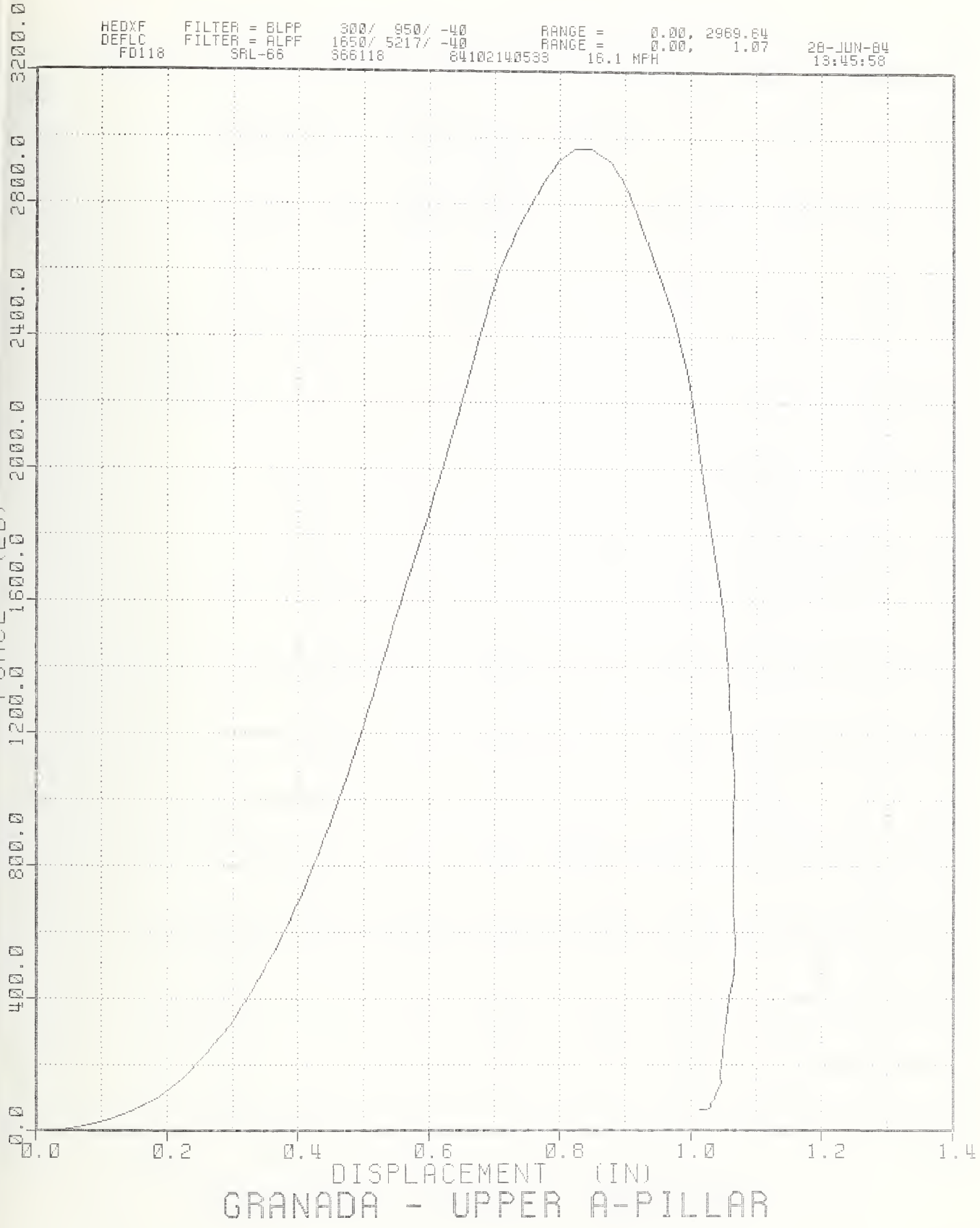
MALIBU FRONT ROOF RAIL

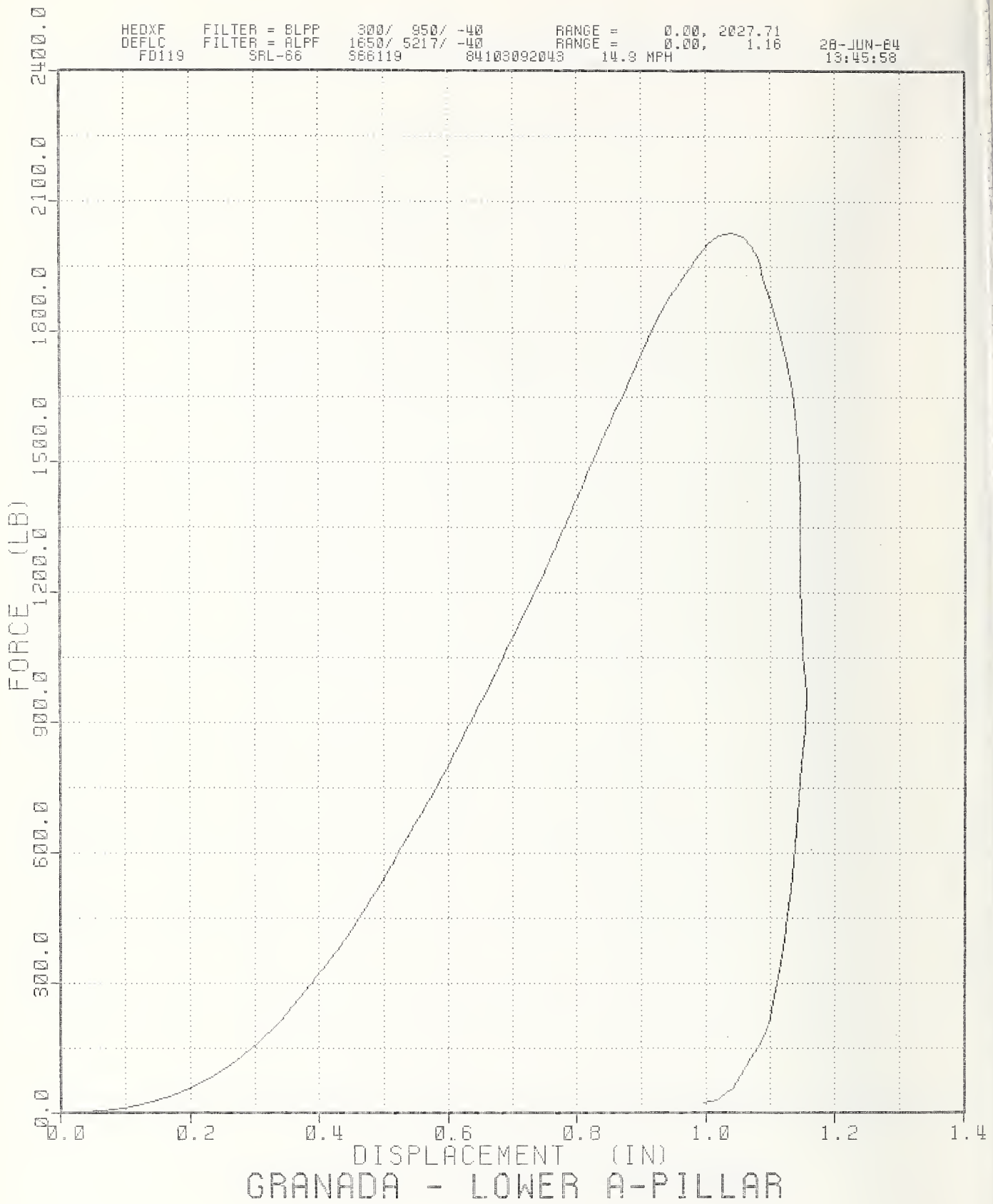
UPPER STRUCTURE MATERIAL AND COVER DATA

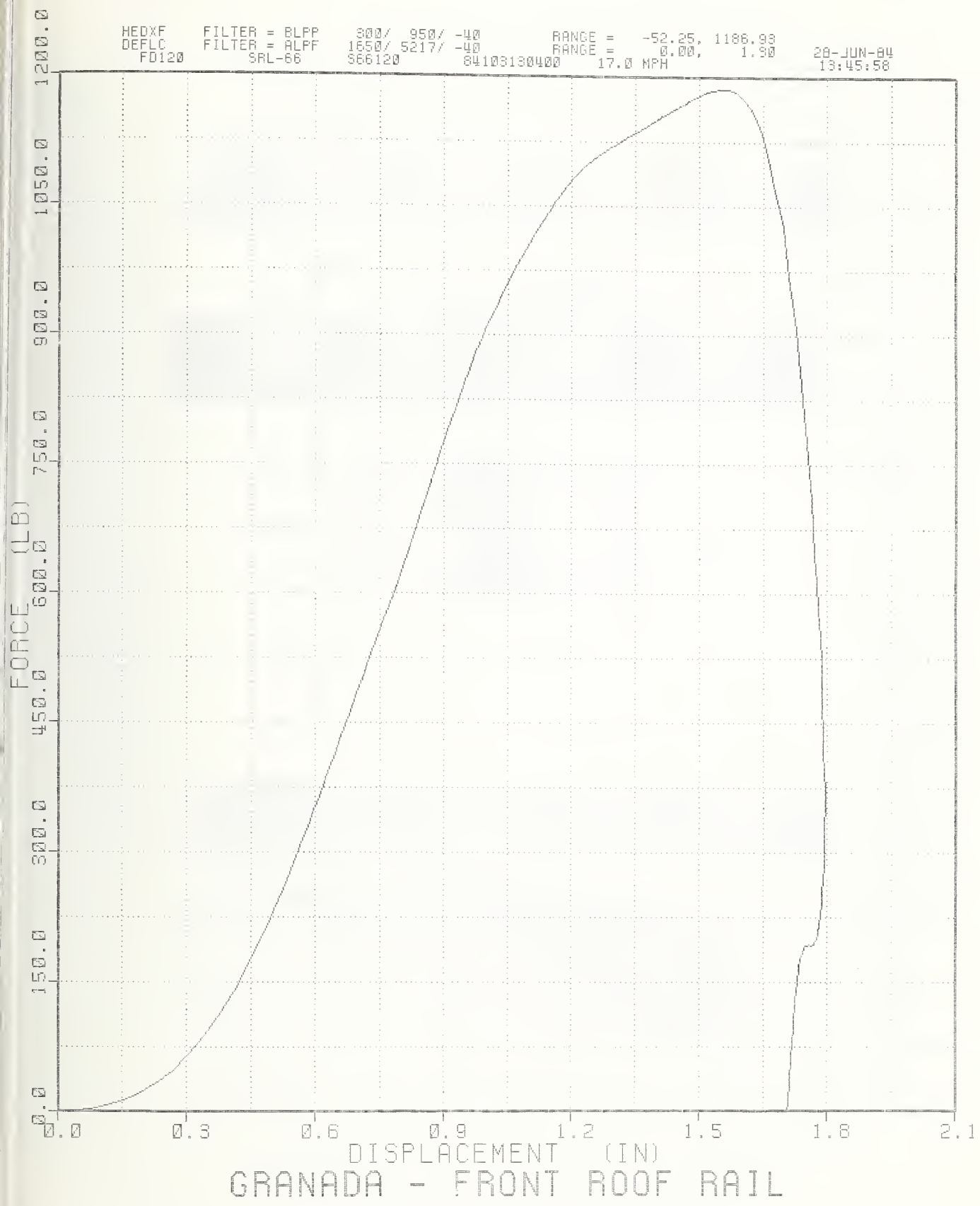
VEHICLE	MALIBU			
		COVER		
STRUCTURE	SHEET METAL GAGE THICKNESS*	TYPE OF MATERIAL	GAGE THICKNESS	STRUCTURE LENGTH
A-PILLAR	0.052"	mild plastic	0.065"	22"
SIDE ROOF RAIL	0.033"	styrofoam /foam & aluminum	1/2" & 0.033"	30"
FRONT ROOF RAIL	0.033" & 0.054"	styrofoam /foam & aluminum	1/2" & 0.033"	
B-PILLAR				

* If more than one gage thickness is listed, the first is that of the impacted surface.

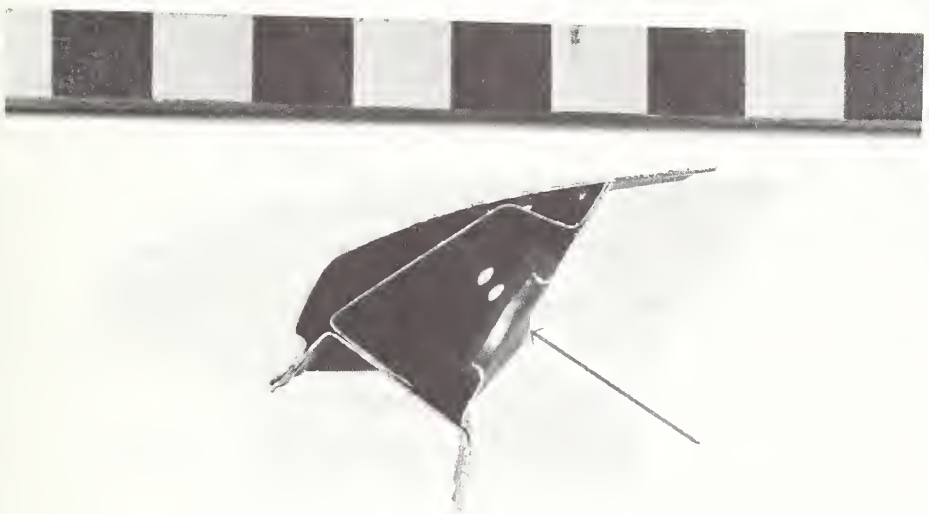

HEDXF FILTER = BLPF 300/ 950/ -40 RANGE = -2.64, 1694.64
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.79
28-JUN-84
FD117 SRL-66 886117 84102131155 16.0 MPH
13:45:58
FORCE (LB)
0.0
250.0
500.0
750.0
1000.0
1250.0
1500.0
1750.0
2000.0
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
DISPLACEMENT (IN)
GRANADA - SIDE ROOF RAIL


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = 0.00, 2969.64
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.07
FD118 SRL-66 366118 84102140533 16.1 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
400.0
800.0
1200.0
1600.0
2000.0
2400.0
2800.0
3200.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISPLACEMENT (IN)
GRANADA - UPPER A-PILLAR

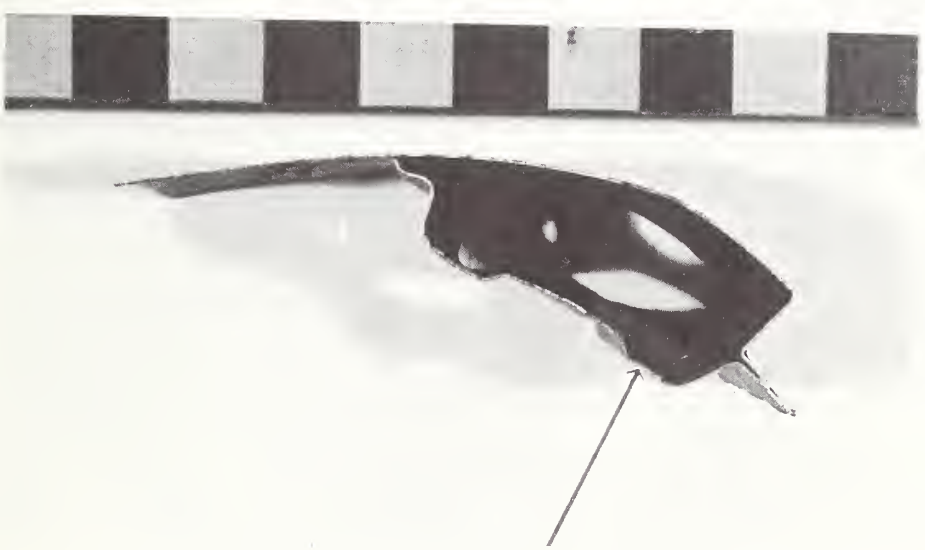

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = 0.00, 2027.71
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.16
FD119 SRL-66 S86119 84103092043 14.8 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
300.0
600.0
900.0
1200.0
1500.0
1800.0
2100.0
2400.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISPLACEMENT (IN)
GRANADA - LOWER A-PILLAR


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -52.25, 1186.93
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.90 28-JUN-84
FD120 SRL-66 S66120 84103130400 17.0 MPH 13:45:58
FORCE (LB)
0.0
150.0
300.0
450.0
600.0
750.0
900.0
1050.0
1200.0
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
DISPLACEMENT (IN)
GRANADA - FRONT ROOF RAIL

Granada A-pillar



Granada Side Roof Rail

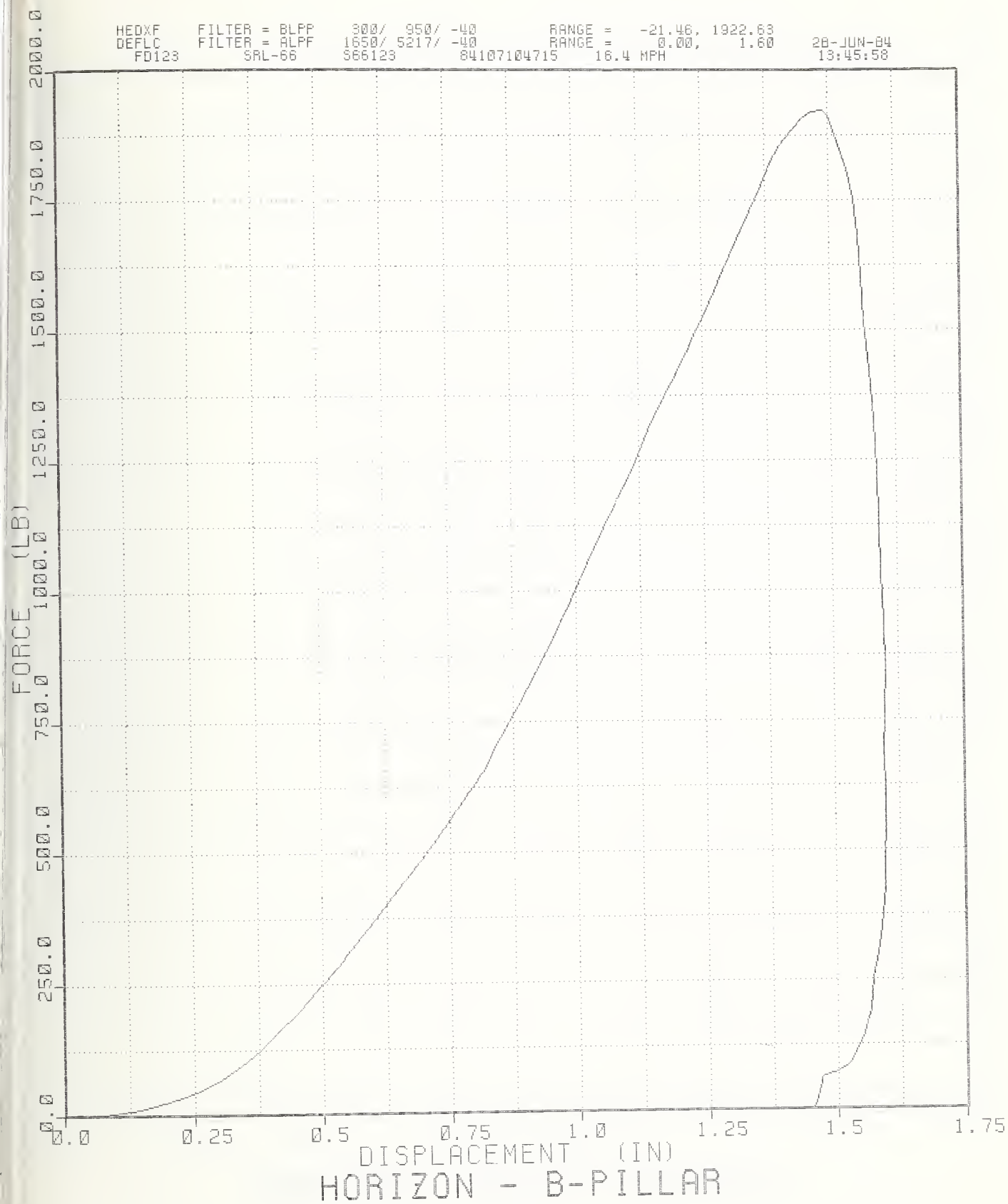


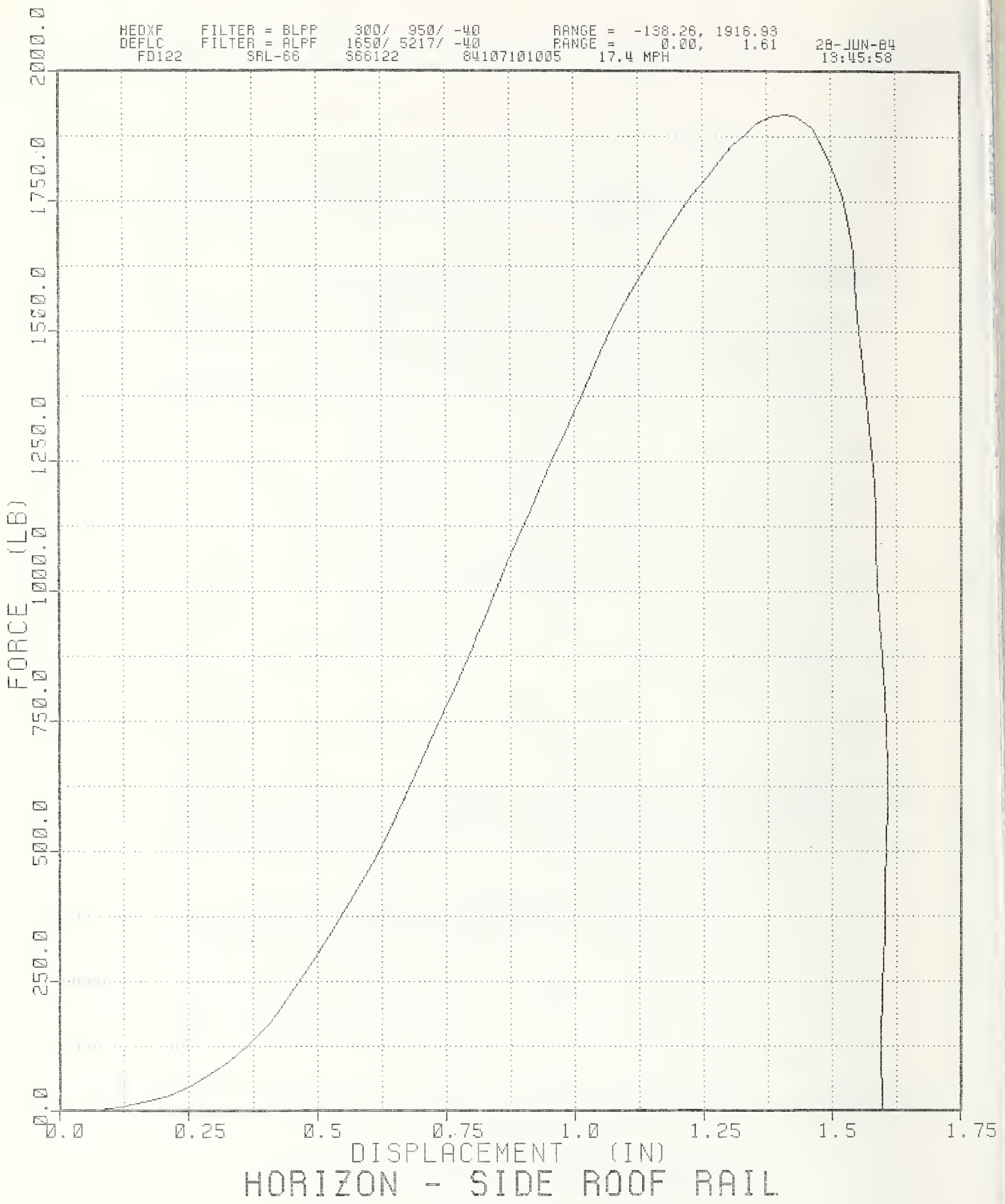
Granada Front Roof Rail

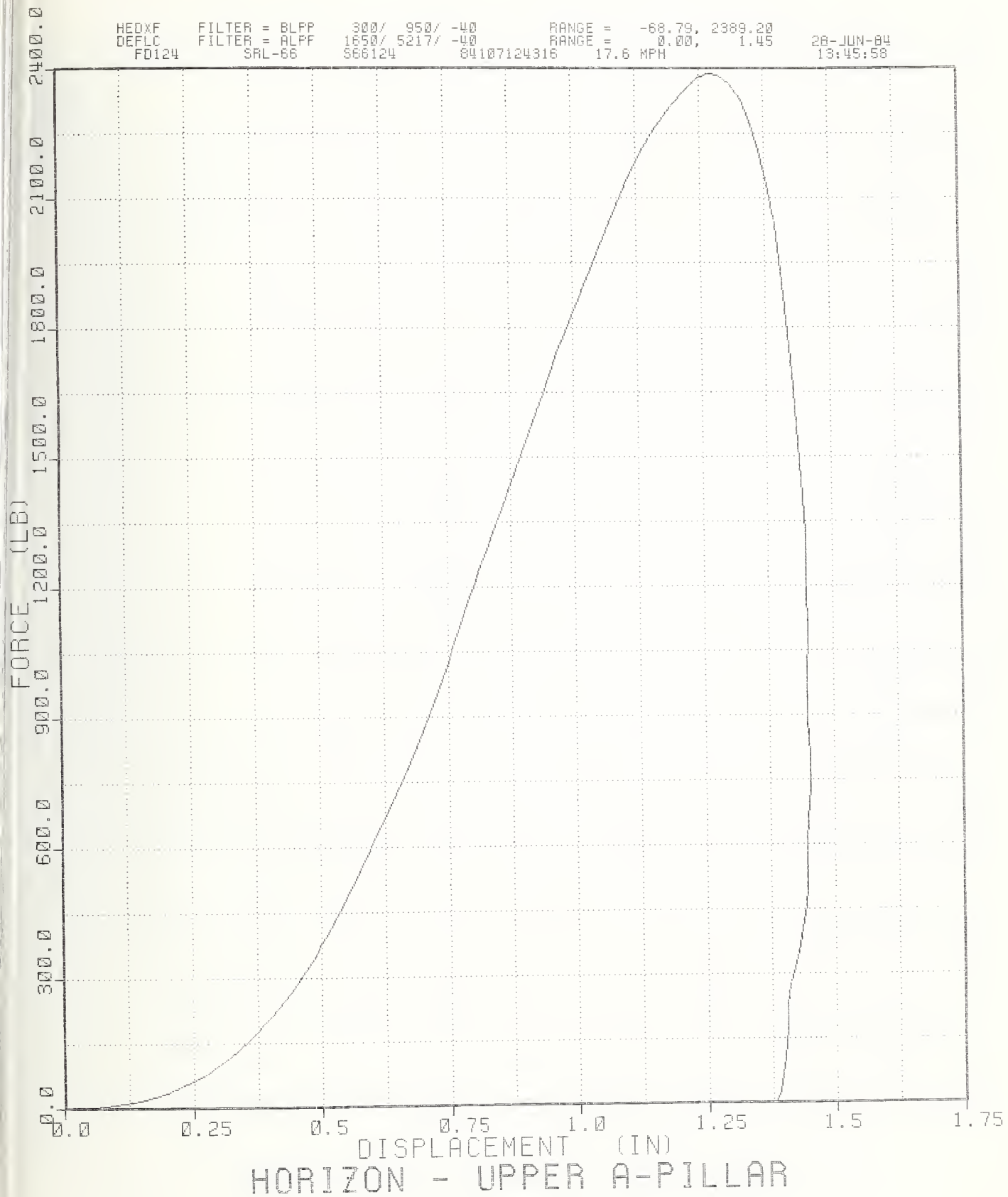
UPPER STRUCTURE MATERIAL AND COVER DATA

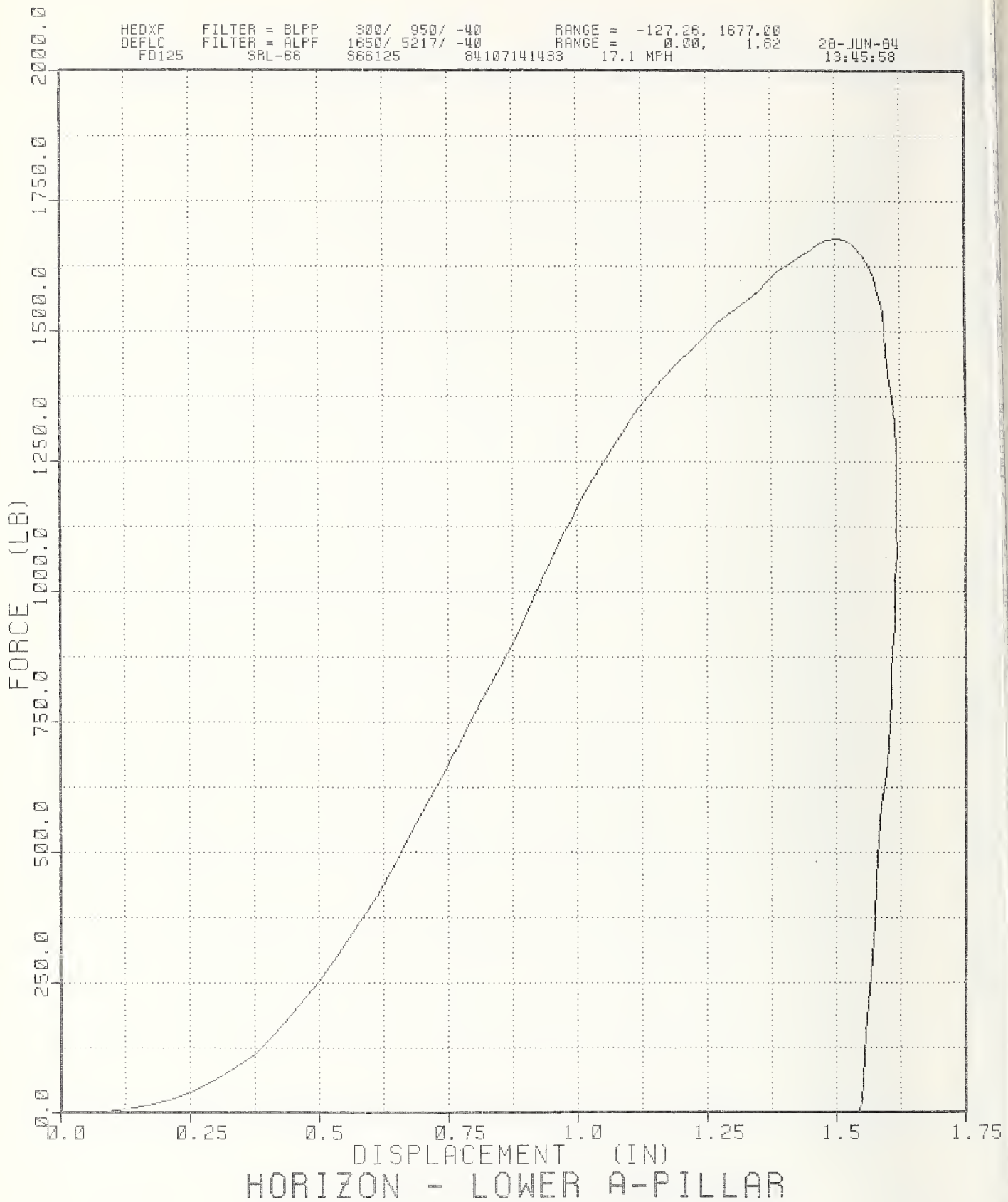
VEHICLE	GRANADA			
STRUCTURE	SHEET METAL GAGE THICKNESS*	COVER TYPE OF MATERIAL	COVER GAGE THICKNESS	STRUCTURE LENGTH
A-PILLAR	0.050" & 0.058"	hard plastic	0.103"	24"
SIDE ROOF RAIL	0.027" & 0.035"	steel strip & cardboard /foam	0.035" & 1/8"	26"
FRONT ROOF RAIL	0.035"	steel strip & cardboard /foam	0.035" & 1/8"	
B-PILLAR				

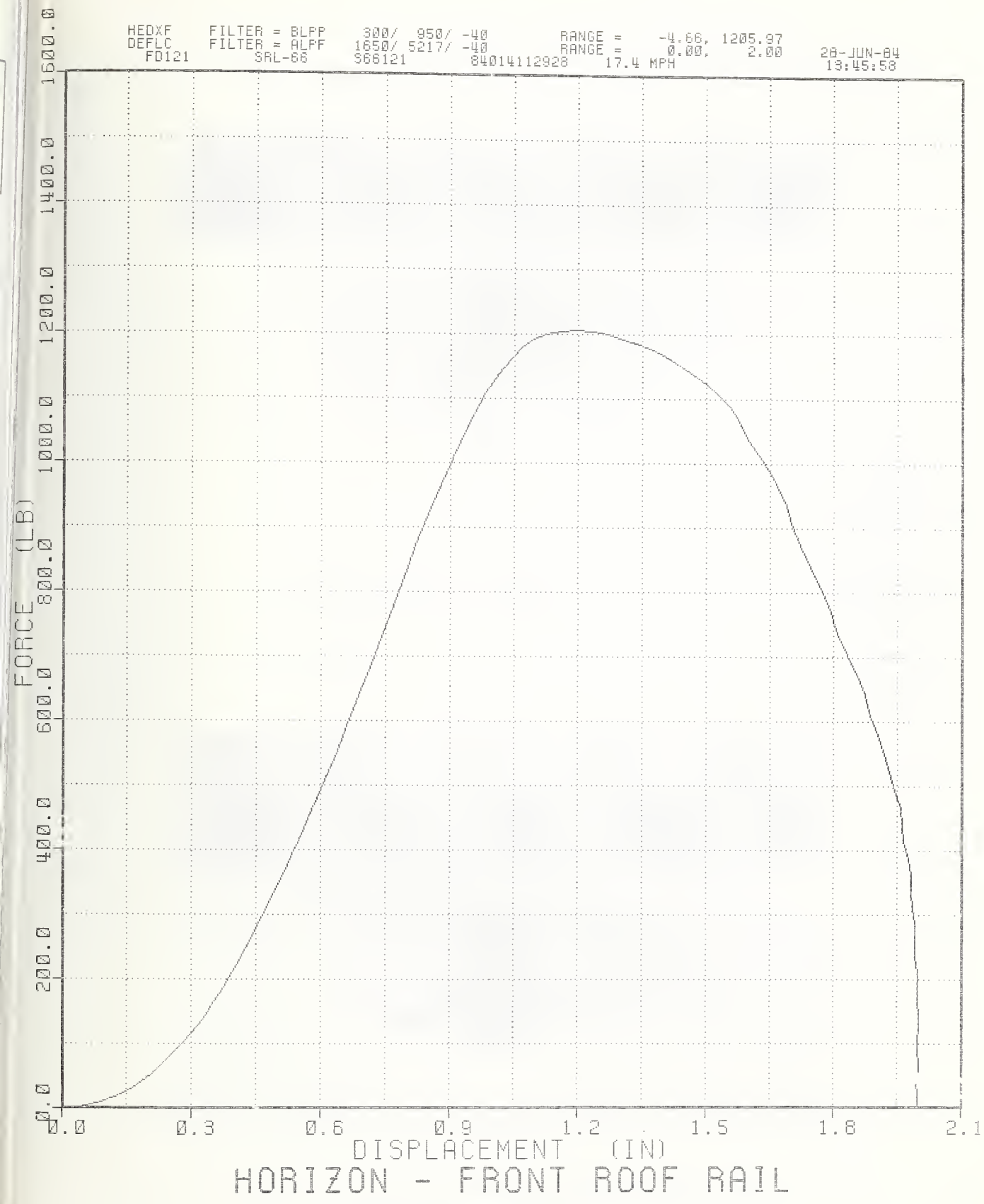
* If more than one gage thickness is listed, the first is that of the impacted surface.


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -21.46, 1922.63
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.60 28-JUN-84
FD123 SRL-66 S66123 84107104715 16.4 MPH 13:45:58
FORCE (LB)
2000.0
1750.0
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
0.0
0.25
0.5
0.75
1.0
1.25
1.5
1.75
DISPLACEMENT (IN)
HORIZON - B-PILLAR

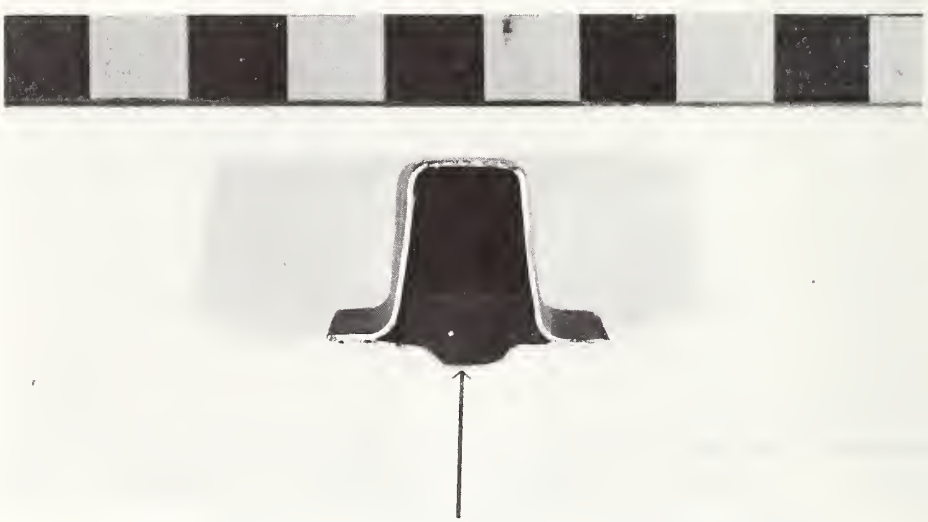

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -138.26, 1916.93
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.61 28-JUN-84
FD122 SRL-66 S66122 84107101005 17.4 MPH 13:45:58
FORCE (LB)
2000.0
1750.0
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
0.0
0.25
0.5
0.75
1.0
1.25
1.5
1.75
DISPLACEMENT (IN)
HORIZON - SIDE ROOF RAIL


HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -68.79, 2389.20
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.45 28-JUN-84
FD124 SRL-66 866124 84107124316 17.6 MPH 13:45:58
FORCE (LB)
2400.0
2100.0
1800.0
1500.0
1200.0
900.0
600.0
300.0
0.0
0.0
0.25
0.5
0.75
1.0
1.25
1.5
1.75
DISPLACEMENT (IN)
HORIZON - UPPER A-PILLAR

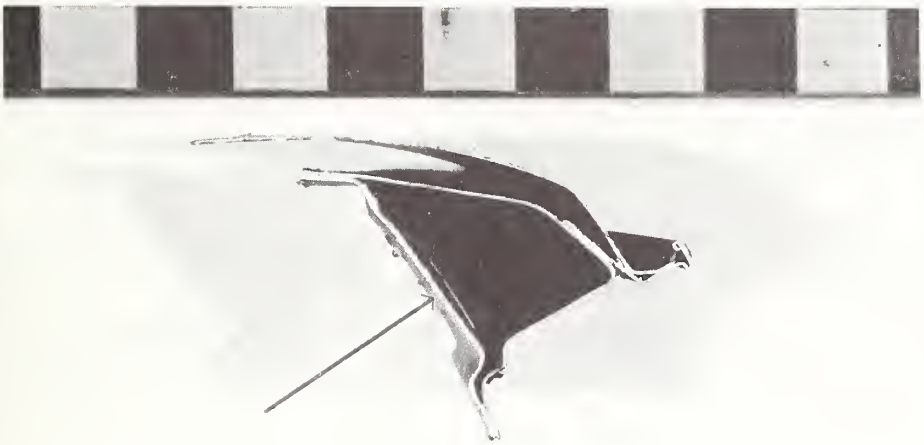

HEDXF FILTER = BLPP 300/ 950/ -40 RANGE = -127.26, 1677.00
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 1.62 28-JUN-84
FD125 SRL-66 S66125 84107141433 17.1 MPH 13:45:58
FORCE (LB)
2000.0
1750.0
1500.0
1250.0
1000.0
750.0
500.0
250.0
0.0
0.0
0.25
0.5
0.75
1.0
1.25
1.5
1.75
DISPLACEMENT (IN)
HORIZON - LOWER A-PILLAR


HEDXF FILTER = BLPF 300/ 950/ -40 RANGE = -4.66, 1205.97
DEFLC FILTER = ALPF 1650/ 5217/ -40 RANGE = 0.00, 2.00
FD121 SRL-66 566121 84014112928 17.4 MPH
28-JUN-84
13:45:58
FORCE (LB)
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
DISPLACEMENT (IN)
HORIZON - FRONT ROOF RAIL

Horizon A-pillar



Horizon B-pillar



Horizon Side Roof Rail

Horizon Front Roof Rail

UPPER STRUCTURE MATERIAL AND COVER DATA

VEHICLE	HORIZON			
STRUCTURE	SHEET METAL GAGE THICKNESS*	COVER		STRUCTURE LENGTH
		TYPE OF MATERIAL	GAGE THICKNESS	
A-PILLAR	0.042" & 0.033"	hard plastic	0.110"	24"
SIDE ROOF RAIL	0.042" & 0.033"	cardboard & foam	1/4"	19"
FRONT ROOF RAIL	0.033"	steel strip & cardboard /foam	0.030" & 1/4"	
B-PILLAR	0.033" & 0.055"	hard plastic	0.105"	

* If more than one gage thickness is listed, the first is that of the impacted surface.

APPENDIX C

Vehicle Selection

Twelve vehicles were selected for use in the investigation of side interior stiffnesses as part of SRL-66. The first step in this selection was to determine the mix of foreign and domestic cars. Automotive News listed the number of the various models sold in the U.S. in 1982 (see figures C.1 and C.2). It should be noted that the Automotive News considered cars built in the U.S. to be domestic. For the purposes of this study, it was judged that vehicles of foreign design would be considered foreign, regardless of where they were built. Therefore, the total number of domestic cars sold in the U.S. in 1982 5,665,494 (71%). Likewise, the total number of foreign cars sold in the U.S. in 1982 was 2,312,076 (29%). From this it was determined that 3 cars would be foreign and 9 would be domestic.

Another selection criterion was curb weight of the vehicles. Using curb weights of 1983 cars, standard equipment, the mean was found to be 2675 pounds. A two standard deviation window about this mean would therefore include 95.5% of the data. Using the assumed weight distribution for 1985 vehicles as estimated by Carl Ragland from the NHTSA Automobile Characteristics Data Base, each body style group was assigned to one of the following weight categories:

1 -- 1875-2250 lb.
2 -- 2250-2525 lb.
3 -- 2525-2750 lb.
4 -- 2750-3000 lb.
5 -- 3000-3440 lb.

Since 60% of the cars sold in the U.S. were from categories 1 and 2, three cars were selected for each of these and two from each of the other categories. Also since most of the top selling foreign cars were of category 1, two of the three category 1 models were to be foreign. The third foreign model was of category 2.

In addition, a Rabbit and a Phoenix were immediately available for testing so it was decided that these would be two of the cars selected. Since these were in categories 1 and 2, respectively, one domestic model and one foreign model were yet to be selected for each of these categories. The six remaining larger cars would all be domestic.

Table C.1 lists the top selling foreign models and the number sold in the U.S. These

DOMESTIC CAR SALES

	Dec. 21 to Dec. 31, 1982	Same Period, 1981	December, 1982	Same Month, 1981	Jan. 1 to Dec. 31, 1982	Same Period, 1981
Renault Alliance	.....	.....	8,542	.....	30,173	.....
Spirit	.....	.....	1,002	1,232	16,182	33,504
Concord	.....	.....	1,633	2,958	30,872	59,846
Pacer	.....	.....	.....	.....	.....	111
Eagle	.....	.....	2,580	3,551	35,206	43,221
AMERICAN MOTORS*	3,500	2,500	13,757	7,741	112,433	136,682
Horizon	1,590	1,700	3,943	3,822	46,907	75,377
Turismo/TC3	1,325	1,043	3,284	2,779	39,794	51,815
Reliant/Volare	3,922	4,491	12,034	12,240	146,762	196,997
Plymouth	210	187	465	526	18,255	1,409
Total Plymouth	7,047	7,421	19,726	19,367	251,628	325,598
LeBaron	.....	199	.....	398	.....	36,311
LeBaron K	2,540	1,580	6,315	4,906	88,575	10,680
Cordoba	430	506	957	1,339	15,828	23,904
New Yorker 5th Ave	1,832	912	4,664	2,546	62,725	5,894
E-Class	1,343	.....	3,177	.....	9,122	.....
Chrysler New Yorker E	96	.....	119	.....	119	17,080
Total Chrysler	6,241	3,197	15,232	9,189	176,369	93,869
Total Imperial	89	128	194	272	2,601	4,649
Omni	1,506	1,317	3,830	3,322	40,002	56,036
Charger/024	1,436	1,139	3,564	3,233	41,275	51,743
Aries/Aspen	4,070	3,518	11,512	9,389	113,076	149,653
Dodge 400	1,261	451	3,035	1,468	28,946	3,150
Diplomat	388	451	949	1,119	24,866	25,598
Mirada/Magnum	204	288	427	686	7,316	13,947
Dodge 600	1,014	.....	2,485	.....	5,624	.....
Dodge St. Regis	.....	.....	.....	.....	.....	5,628
Total Dodge	9,879	7,164	25,802	19,217	261,105	305,757
CHRYSLER CORP.	23,256	17,910	60,954	48,045	691,703	729,873
Pinto	.....	.....	.....	.....	.....	10,037
EXP	1,001	990	2,658	2,768	39,021	54,502
Escort	9,714	5,725	23,684	14,185	337,667	284,907
Mustang	3,461	2,341	8,688	5,866	119,526	154,985
Fairmont	4,943	3,160	14,457	8,736	139,056	182,909
Granada	1,044	2,867	3,051	7,647	94,750	106,996
Thunderbird	479	1,277	1,347	3,424	42,585	69,775
LTD '83	4,499	.....	11,105	.....	26,620	.....
Ford Crown Victoria	4,256	2,809	11,375	7,720	126,065	113,109
Ford Division	29,399	19,169	76,365	50,346	925,490	977,220
Bobcat	.....	.....	.....	.....	.....	2,169
LN7	420	308	1,060	1,204	13,107	18,217
Lynx	2,045	1,358	5,675	4,037	95,959	92,809
Zephyr	1,019	661	3,063	2,001	42,363	50,603
Cougar/Monarch	360	1,043	899	3,224	40,829	46,750
XR-7	142	356	454	1,078	15,609	28,706
Capri	979	451	2,740	1,466	31,280	47,151
Marquis '83	1,512	.....	4,137	.....	10,645	.....
Mercury Grd. Marquis	2,570	1,490	7,411	4,305	77,348	53,145
TOTAL Mercury	9,047	5,687	25,439	17,315	327,142	339,550
Cont./Versailles	547	594	1,484	1,475	22,611	4,919
Lincoln	1,714	468	4,660	1,480	42,537	29,178
Mark VI	1,052	443	2,630	1,420	27,920	29,733
Total Lincoln	3,313	1,505	8,774	4,375	93,068	63,830
L-M Division	12,360	7,192	34,215	21,690	420,208	403,380
FORD MOTOR	41,759	26,361	110,578	72,036	1,345,698	1,380,600
Skyhawk	1,384	.....	4,080	.....	46,942	.....
Skylark	2,211	4,217	7,831	11,649	141,766	200,460
Century FD	2,756	920	9,549	2,602	99,873	2,691
Regal Sedan	1,577	2,503	4,961	6,883	78,860	123,676
Regal Coupe	2,749	4,083	8,370	10,926	143,309	208,329
LeSabre	2,564	2,598	7,890	7,119	108,989	82,263
Electra	1,522	1,840	4,854	4,849	59,599	57,234
Riviera	997	1,517	3,235	3,979	43,670	47,964
Buick Division	15,760	17,678	50,770	48,007	723,011	722,617
Cimarron	640	418	1,941	1,212	13,774	14,604
Seville	945	613	2,543	1,719	24,029	22,724
Cadillac	4,930	4,582	13,937	12,884	154,229	138,948
Eldorado	2,029	1,731	5,254	4,785	57,263	54,389
Cadillac Division	8,544	7,344	23,675	20,600	249,295	230,665
Chevette	4,380	5,141	11,946	16,711	231,927	346,307
Cavalier/Monza	3,761	1,611	10,300	5,312	121,392	88,072
Citation/Nova	4,238	5,248	12,073	15,946	186,782	300,184
Camaro	4,093	1,249	11,992	2,588	182,848	94,606
Celebrity	3,950	494	12,005	1,287	101,311	1,361
Malibu	2,267	2,833	7,457	9,348	110,736	211,130
Monte Carlo	2,214	2,490	6,244	7,448	98,954	161,158
Chevrolet	4,770	4,840	14,102	14,896	204,193	210,424
Corvette	541	405	1,437	1,153	22,477	29,039
Chevrolet Division	30,214	24,311	87,556	74,689	1,260,620	1,442,218
Firenza/Starfire	897	.....	2,538	.....	28,282	.....
Omega	1,173	1,712	3,778	4,757	72,392	109,981
Cutlass Ciera	3,236	1,048	9,409	2,716	113,921	2,882
Cutlass	.....	2,996	.....	9,264	.....	187,952
Supreme	5,343	4,137	16,618	12,248	280,566	266,070
Olds 88	4,315	3,618	13,238	10,756	180,840	158,662
Olds 98	2,515	2,613	7,721	7,343	89,222	84,583
Toronado	844	782	2,637	2,557	34,362	38,609
Oldsmobile Division	18,323	16,906	55,939	49,641	799,585	848,739
T-1000	1,416	1,101	3,560	3,721	51,257	55,868
J-2000/Sunbird	1,901	841	4,976	3,180	57,048	75,884
Phoenix	1,322	1,116	3,763	3,896	49,527	82,285
Firebird	3,288	661	9,182	1,595	105,686	52,188
6000	2,414	459	6,617	1,262	55,794	1,325
Bonneville/Lemans	1,956	1,518	5,367	4,715	76,063	73,988
Grand Prix	1,977	1,731	5,323	5,862	83,598	128,236
Pontiac	.....	406	.....	1,502	4,176	82,620
Pontiac Division	14,274	7,833	38,788	25,733	483,149	552,394
GENERAL MOTORS	87,115	74,072	256,728	218,670	3,515,660	3,796,696
VOLKSWAGEN	2,836	5,408	6,031	11,088	91,166	162,445
DOMESTIC TOTAL	158,466	126,251	448,048	357,530	5,756,660	6,206,298
IMPORT TOTAL	.....	.....	183,827	165,219	2,220,910	2,325,218
INDUSTRY TOTAL	.....	.....	631,875	522,749	7,977,570	8,531,514

Figure C.1

IMPORT SALES BY MODEL

	November, 1982	November, 1981	Jan.-Nov., 1982	Jan.-Nov., 1981
Alfa Romeo	184	171	1,953	2,033
Audi	3,791	4,057	41,877	46,230
4000	951	1,065	12,169	17,421
4000d	286	43	2,803	43
5000	1,433	1,709	15,226	15,883
5000d	33	363	1,308	5,731
5000 Turbo	302	473	3,771	5,016
5000 TD	317	.....	2,546	.....
Coupe	433	404	3,831	2,136
Quattro	36	.....	223	.....
BMW	4,364	2,417	46,178	37,536
320	3,178	1,935	32,603	29,136
528	745	271	9,089	5,396
633	96	81	1,268	977
733	345	130	3,218	2,027
Chrysler/Mitsubishi	5,468	8,380	95,153	102,651
Colt	3,733	3,393	70,221	39,602
Sapporo	945	830	11,785	12,451
Challenger	790	883	13,147	11,680
Champ '82	.....	3,274	.....	38,918
DeLorean	.....	654	2,830	2,367
Fiat	404	1,191	13,540	30,961
Strada	92	229	4,364	6,555
Brava	34	222	2,392	7,135
X-1/9	49	234	2,247	6,138
Spider	229	506	4,537	11,114
Honda	29,618	22,010	337,779	343,623
Civic	11,541	11,097	122,692	144,385
Accord	15,458	9,058	178,775	158,475
Prelude	2,619	1,855	36,312 ✓	40,763
Isuzu	1,698	1,432	14,103	16,602
Jaguar	1,384	469	9,130	4,135
Lancia	75	41	1,050	1,018
Mazda	14,712	11,995	149,865	155,810
GLC	5,587	4,069	50,328	58,714
626	4,749	4,402	53,902	56,707
RX-7	4,376	3,524	45,635	40,389
Mercedes-Benz	5,444	4,929	58,564	56,643
240D	895	1,133	12,157	13,131
300D	1,715	980	15,038	12,097
300CD	120	204	1,543	1,240
300TD	215	250	2,585	2,978
300SD	1,281	1,288	14,929	14,829
280E	.....	23	28	1,169
280CE	.....	12	1	581
380SEL	361	230	3,160	2,149
380SL	719	795	7,507	7,071
380SEC/SLC	136	10	1,590	1,306
Miscellaneous	2	4	26	92
Mitsubishi	1,515	.....	2,690	.....
Starion	441	.....	802	.....
Cordia	584	.....	1,017	.....
Tredia	490	.....	871	.....
Nissan	41,362	33,027	430,467	431,746
210	230	11,160	59,287	149,360
Sentra	16,872	.....	116,180	.....
310	1,558	3,808	42,566	74,537
Pulsar	4,313	.....	4,488	.....
510	.....	.....	.....	32,684
Stanza	4,893	4,245	55,550	9,365
Maxima	5,847	3,284	48,655	31,908
200SX	2,663	4,960	45,677	72,335
280ZX	3,323	4,641	52,901	57,590
Hawaii	1,663	926	5,549	3,863
Other	.....	3	.....	105
Peugeot	1,065	1,078	13,106	15,708
504	94	131	1,459	2,325
505	420	130	4,441	2,054
505D	24	105	684	2,065
505TD	448	601	5,553	8,574
604TD	57	90	705	497
Tourist	22	21	264	193
Porsche	1,270	977	12,246	9,983
924	5	292	1,678	2,892
924 Turbo	9	144	641	1,749
944	748	.....	4,110	.....
911SC	387	350	4,036	3,538
928	121	191	1,781	1,786
930 Turbo	.....	.....	.....	18
Renault	3,397	2,885	35,509	28,832
Le Car	2,621	2,214	19,158	18,721
18i	145	671	7,378	10,111
Fuego	631	.....	8,973	.....
Saab	1,902	1,415	17,038	13,326
99	.....	3	1	314
900	418	189	4,111	1,975
900S	424	450	3,751	4,348
Turbo	1,050	769	8,911	6,581
Tourist	10	4	264	108
Subaru	13,512	10,548	138,741	140,855
Toyota	42,792	36,096	484,099	534,718
Starlet	1,339	1,561	18,188	31,042
Corolla	12,744	11,733	162,104	227,872
Tercel	13,247	7,760	121,920	111,517
Celica	8,186	8,440	106,134	94,538
Supra	2,784	1,995	31,261 ✓	13,778
Corona	8	1,065	3,105	21,187
Cressida	3,247	2,314	33,730 ✓	27,219
Land Cruiser	280	172	2,776	1,762
Hawaii	957	1,056	4,881	5,753
Other	.....	.....	.....	50
Volkswagen	6,390	4,369	61,106	76,971
Rabbit Convertible	799	580	8,198	11,431
Jetta	1,866	1,853	18,596	26,072
Vanagon	1,132	655	11,778	10,084
Quantum	1,197	115	10,099	115
Dasher	13	329	616	13,309
Scirocco	1,383	837	11,819	15,960
Volvo	4,712	4,419	68,974	61,397
DL	2,393	2,436	37,882 ✓	37,602
GL	940	865	10,884	9,769
GLT	.....	129	197	3,497
GLT Turbo	739	497	9,591	3,202
GLE/760	178	203	2,569	3,905
DL Diesel	.....	33	516	1,466
GL Diesel	411	199	6,469	219
Coupe	.....	28	78	1,111
Tourist	51	29	788	349
GT	.....	.....	.....	277
TOTAL IMPORTS	185,059	152,560	2,035,998	2,113,027

sales figures are from figure C.2, with the numbers adjusted to include the month of December. From this, the Honda Accord (Category 1) and the Toyota Corolla (category 2) were initially chosen for testing.

Table C.1
TOP SELLING FOREIGN MODELS

MODEL	NO. SOLD
HONDA ACCORD	195,027
TOYOTA COROLLA	176,841
HONDA CIVIC	133,849
TOYOTA TERCEL	133,004
NISSAN SENTRA	126,742
TOYOTA CELICA	115,783
VW RABBIT	91,166

The domestic cars were divided into groups according to body style. For example, the Chevrolet Citation, the Pontiac Phoenix, the Oldsmobile Omega, and the Buick Skylark are all designated as X-body vehicles by GM and are structurally equivalent. Each of these groups was then ranked according to the total number sold in 1982. Table C.2 lists the weight category, make, body style group, and sales of the domestic cars. This list excludes models whose curb weight exceeds 3440 pounds.

The top selling body type from category 1 was Ford's 61D/58D, so the Escort was initially chosen, along with the Accord and the Rabbit, to be a category 1 test vehicle. The top selling category 2 body type was GM's X-body model. This worked out well since a Phoenix had already been chosen as a test vehicle. The next in this category was Chrysler's 21/41 model, so a Reliant would join the Corrolla and the Phoenix as category 2 test vehicles.

Table C.2

TOP SELLING DOMESTIC MODELS

WEIGHT CATEGORY	MAKE	BODY TYPE 2dr/4dr	EXAMPLE MODEL	NO. SOLD
5	GM	G	Malibu	796,023
2	GM	X	Phoenix	450,467
1	Ford	61D/58D	Escort	433,626
3	GM	A	Celebrity	370,899
2	Chry	21/41	Reliant	348,413
4	GM	F	Camaro	288,534
1	GM	T	Chevette	283,184
2	GM	J	Cavalier	267,438
4	Ford	36R/54D	Fairmont	181,419
4	Ford	66D/54D	Grenada	163,499
5	Chry	/41	Gran Fury	135,184
3	Ford	66H/	Mustang	119,184
1	Chry	/44	Omni	86,909
1	Chry	24/	Charger	80,979

The top two selling body types for category 3 were GM's A-body (Celebrity) and Ford's 66H (Mustang). The top two in category 4 were GM's F-body (Camaro) and Ford's 36R/54D (Fairmont). The top two in category 5 were GM's G-body (Malibu) and Chrysler's 41 (Plymouth Gran Fury). These six vehicles were also initially chosen for use in this study.

The initial vehicle selection was as follows:

Weight Category 1 --	Honda Accord Ford Escort Volkswagen Rabbit
Weight Category 2 --	Toyota Corolla Plymouth Reliant Pontiac Phoenix
Weight Category 3 --	Chevrolet Celebrity Ford Mustang
Weight Category 4 --	Chevrolet Camaro Ford Fairmont
Weight Category 5 --	Chevrolet Malibu Plymouth Gran Fury

A Dodge Omni and an AMC Concord were scheduled for use in frontal testing in another Agency project. These two vehicles were therefore chosen for this study as replacements for the Ford Escort and the Ford Fairmont. In addition, a number of vehicles were available that did not require purchase. Some of these were substituted for cars in the initial list if it was judged that they were a reasonable replacement on the basis of weight, body style, and sales. The Honda Accord was replaced by the Honda Civic, the Toyota Corolla was replaced by the Toyota Cressida, the Plymouth Reliant was replaced by the Chevrolet Cavalier, and the Chevrolet Camaro was replaced by the Ford Granada. This led to the final vehicle selection which was as follows:

Weight Category 1 --	Honda Civic (2-dr) Dodge Omni (4-dr) Volkswagen Rabbit (2-dr)
Weight Category 2 --	Toyota Cressida (4-dr) Chevrolet Cavalier (4-dr) Pontiac Phoenix (4-dr)
Weight Category 3 --	Chevrolet Celebrity (4-dr) Ford Mustang (2-dr)
Weight Category 4 --	Ford Granada (2-dr) AMC Concord (4-dr)
Weight Category 5 --	Chevrolet Malibu (2-dr) Plymouth Gran Fury (4-dr)

APPENDIX D

Effective Mass of the Head

A head component test device was built for use in SRL-66. In addition to other factors, the weight of the head impactor was to be determined. Ideally, this weight would be equivalent to the effective dynamic mass of a typical human head. The following discussion describes the steps involved in selecting the impactor's mass.

Hodgson and Thomas reported on two sets of cadaver tests they performed (D.1) (D.2). A test from each of these sets was selected for investigation. Both tests produced forehead impacts by dropping a whole cadaver onto a rigid surface.

The data from these tests were available in graphical form only so the response curves were first put into digital form. Once done, effective head mass was calculated using two methods, balance of forces and impulse/momentum. In both tests, impact force was measured. Integration of this produced the impulse of the impact. This was then divided by the change in velocity over this period, resulting in effective mass.

One of the cadavers showed a linear increase in mass for the first four milliseconds, at which point it leveled off at about 12 1/4 pounds for another four milliseconds. The other cadaver also increased linearly, but for about eight milliseconds. The mass then leveled off very briefly, about one millisecond, to a value of 14 1/2 pounds.

Effective mass of the head was also calculated for these two cadaver tests using a force balance. Neither of these tests produced meaningful results by this method. Since the two methods used here did not produce results that indicated a single representative effective head mass, data from other types of testing were investigated.

Forehead impacts were performed on Part 572 dummies in SRL-29 (D.3) and the results were analyzed here to determine effective head mass. High speed films of one of these tests was examined to determine head orientation and rotation during the test.

Once again, the results did not suggest a representative value for head mass. The film showed there was little or no head rotation during the first seven milliseconds after impact. An impulse/momentum analysis over this time period

revealed that effective mass increases linearly at a rate of about 2 pounds per millisecond. The average weight over this period was about 10 pounds. Finally, effective mass was calculated using a force balance. The results were so erratic that they were useless.

Another source of information was a study done by G.S. Nusholtz et al. (D.4). This study showed that effective mass of the head can be less than the static mass of the head since it is not a rigid body. He performed tests on Part 572 dummies in his research. These tests produced values for effective head mass of 4 to 6 1/2 pounds. By his theory, the effective mass of the dummy heads should be equal to the weight of the rigid skulls of these heads for hard surface impacts. A Part 572 aluminum skull weighs 7 1/4 pounds while the headskin adds another 3 3/4 pounds to this.

Three different groups of cadavers were then tested for this same effect. Each group produced masses within a range, which averaged to about 8 1/2 pounds.

A study by R.L. Stalnaker et al. (D.5) examined this effect on cadavers more closely. Their results clearly indicated that the human head does not react as a rigid body. The brain, skin, blood vessels, etc. are not rigidly connected to the skull and therefore do not react as quickly and also do not respond to higher frequency impacts. In the frequency range of interest, the effective head mass found from these tests was 6 to 7 pounds.

All of this tended to indicate that to truly reproduce the effective mass of a human head in hard surface impacts, the surrogate would have to have an initial mass of about 6 pounds, and then increase during impact to some larger value. This upper value was not well defined since cadaver test results varied greatly in this respect.

A reasonable choice for the impactor mass would therefore be somewhere in the middle of this range. The average effective mass of the Nusholtz cadaver tests was about 8 1/2 to 9 pounds. The head impactor was therefore constructed to have a rigid body weight of 9 pounds. The modified headskin used for this impactor weighed 1.4 pounds, which brought the total impactor weight to 10.4 pounds. The rigid impactor, which had no headskin, was also built to weigh 9 pounds.

REFERENCES

D.1) "Comparison of Head Acceleration Injury Indicies in Cadaver Skull Fracture"; V.R. Hodgson, L.M. Thomas; School of Medicine, Wayne State University; Paper no. 710854 at the 15th Stapp Car Crash Conference; November 1971.

D.2) "Head Impact Response"; V.R. Hodgson, L.M. Thomas; School of Medicine, Wayne State University; Vehicle Research Institute Report no. VRI 7.2; 1973.

D.3) "State-of-the-Art Dummy Selection"; NHTSA Project no. SRL-29; September-December 1982 progress reports.

D.4) "Response of the Cervical Spine to Superior-Inferior Head Impact"; G.S. Nusholtz, J.W. Melvin, D.F. Huelke, N.M. Allem, J.G. Blank; Highway Safety Research Institute, The University of Michigan; Paper no. 811005 at the 25th Stapp Car Crash Conference; September 1981.

D.5) "Head Impact Response"; R.L. Stalnaker, J.W. Melvin, G.S. Nusholtz, N.M. Allem, J.B. Benson; Highway Safety Research Institute, The University of Michigan; Paper no. 770921 at the 21st Stapp Car Crash Conference; October 1977.

APPENDIX E

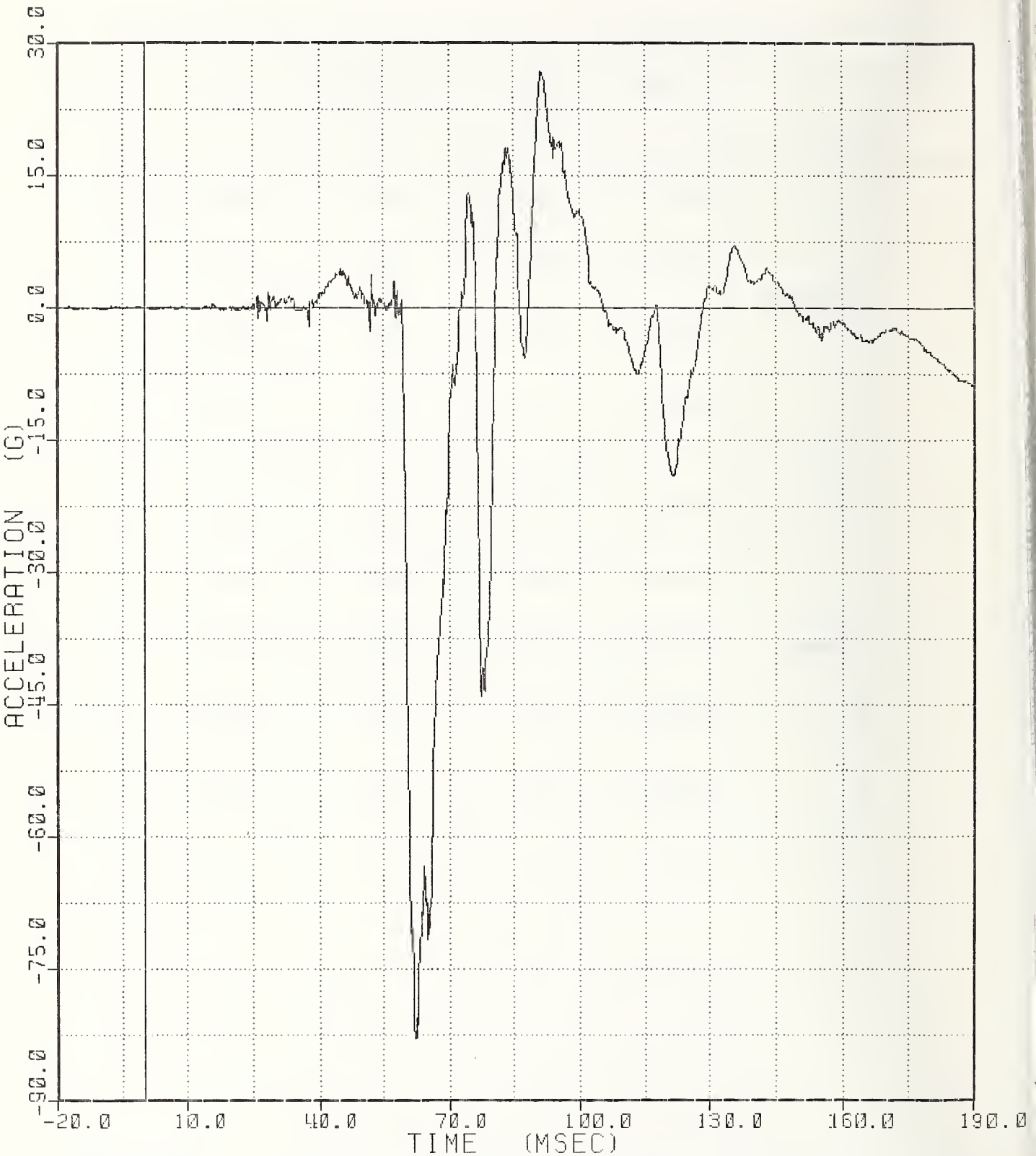
HYGE Sled Test Results

This section contains a description of each of the sled tests performed in this study. This includes the peak resultant head accelerations, the calculated HIC's, and the actual sled velocities for both the Citation and the Rabbit sled bucks.

Plots of the head accelerations in the lateral, longitudinal, and vertical directions as well as the resultants of these are also included.

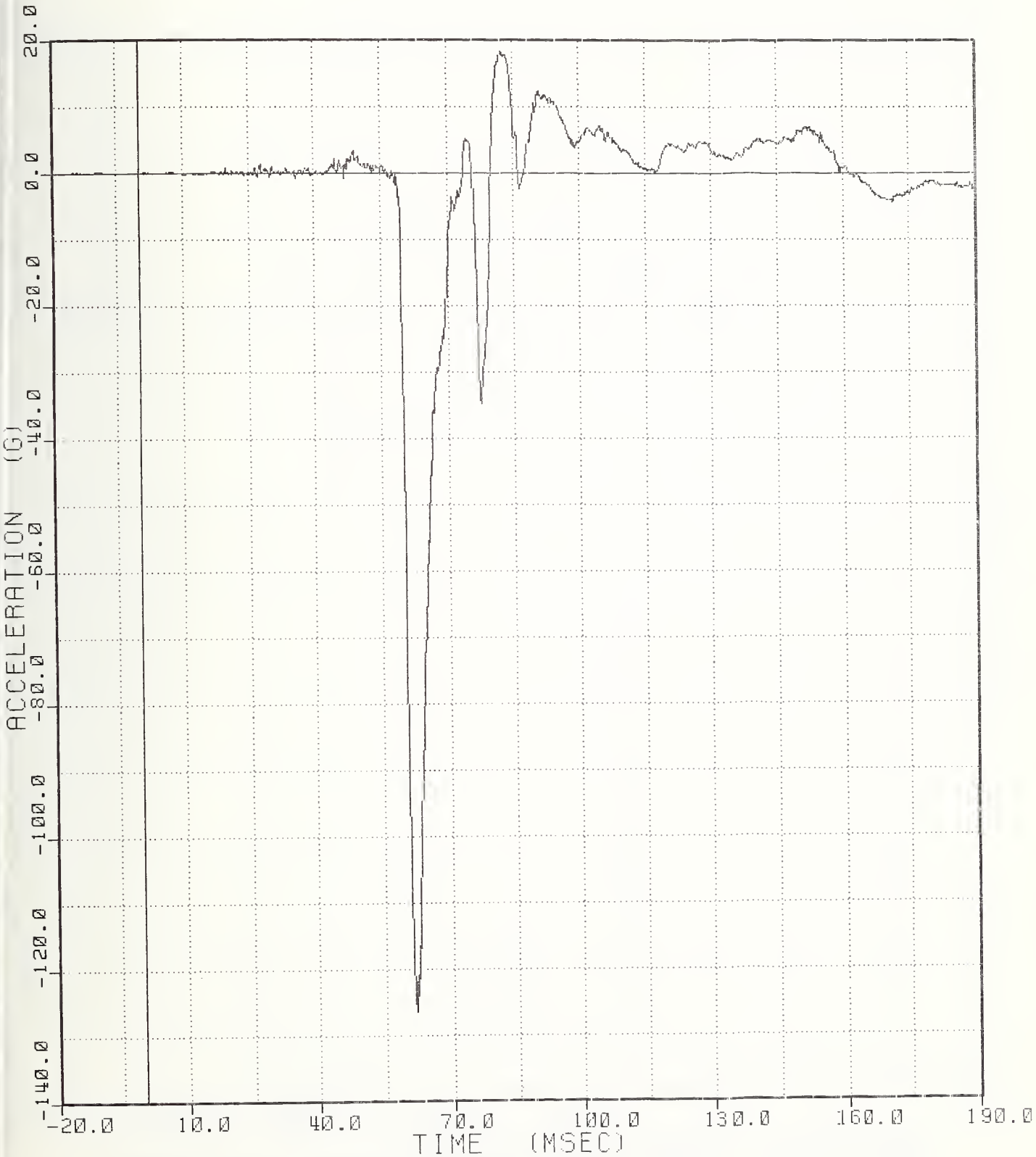
SLED BUCK	TEST NUMBER	SLED VELOCITY (mph)	RESULTANT ACCELERATION (g)	HIC
CITATION	SRL66--1	20.08	165.9	917.1
	SRL66--2	20.14	228.8	1678.8
	SRL66--3	20.40	304.2	2383.9
	SRL66--4	15.20	191.2	798.9
RABBIT	SRL66--5	19.68	116.1	624.3
	SRL66--6	20.02	180.2	1018.7
	SRL66--7	20.21	156.7	1075.5
	SRL66--8	15.16	93.2	448.0
	SRL66--9	15.15	94.9	414.6

SRL661 VRTC SRL66 - 1 83342 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -82.987 @ 62.2500 26.872 @ 91.3750



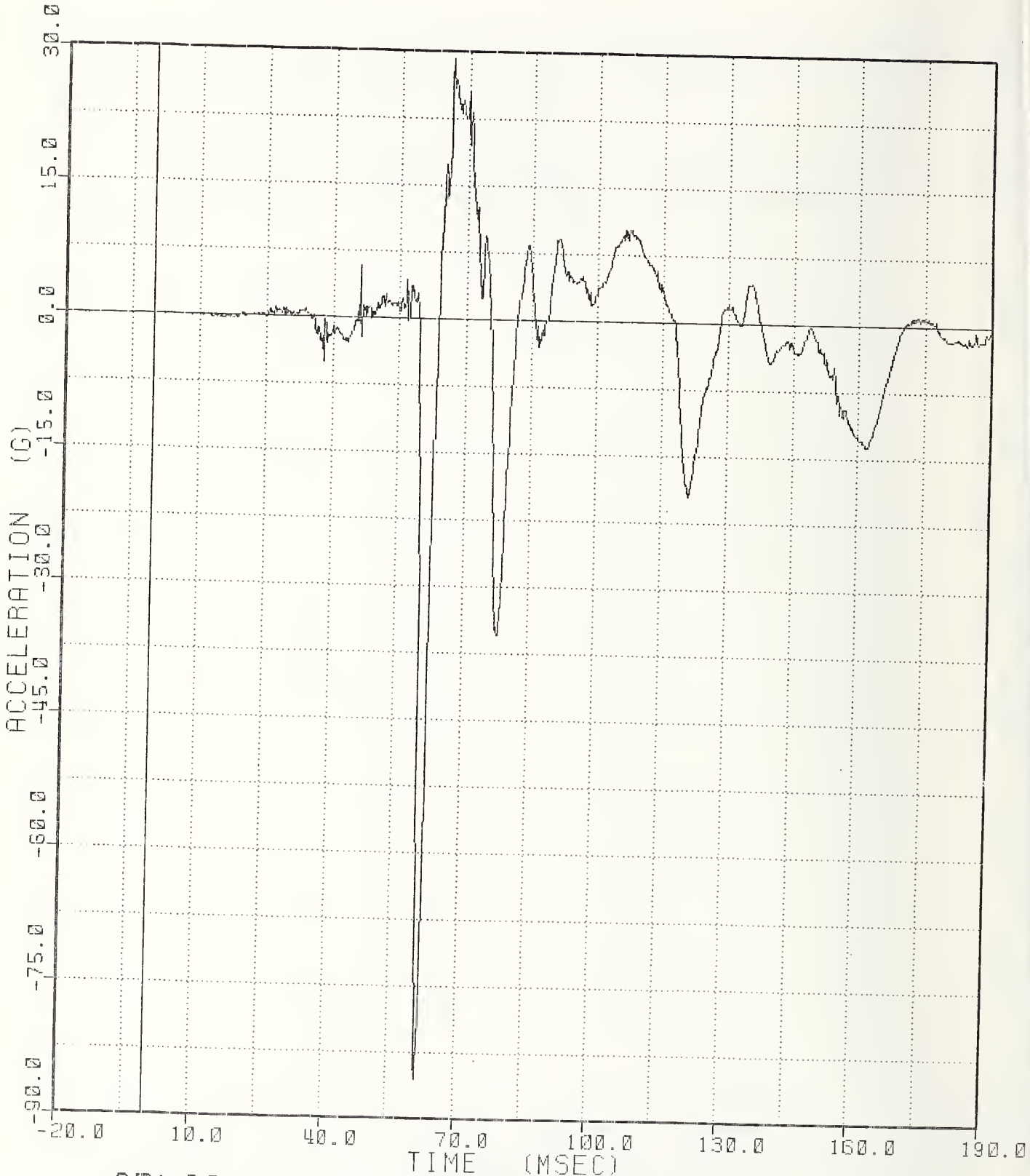
SRL66-1 LONGITUDINAL HEAD ACCELERATION

SRL661 VRTC SRL66 - 1 83342 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -126.347 @ 62.0000 18.343 @ 82.3750



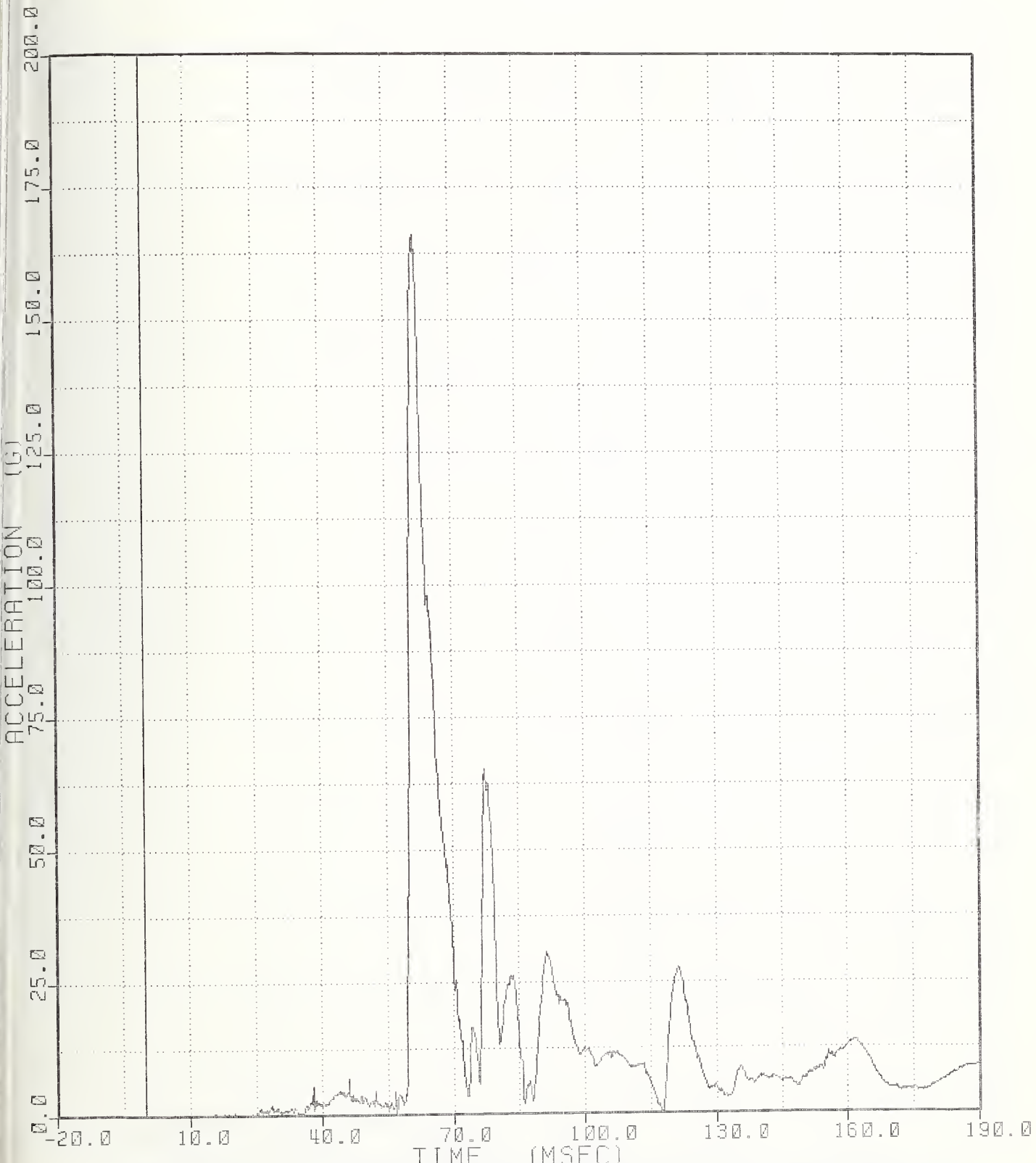
SRL66-1 LATERAL HEAD ACCELERATION

SRL661 VRTC SRL66 - 1 83342 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -85.517 @ 61.2500 29.186 @ 66.6250



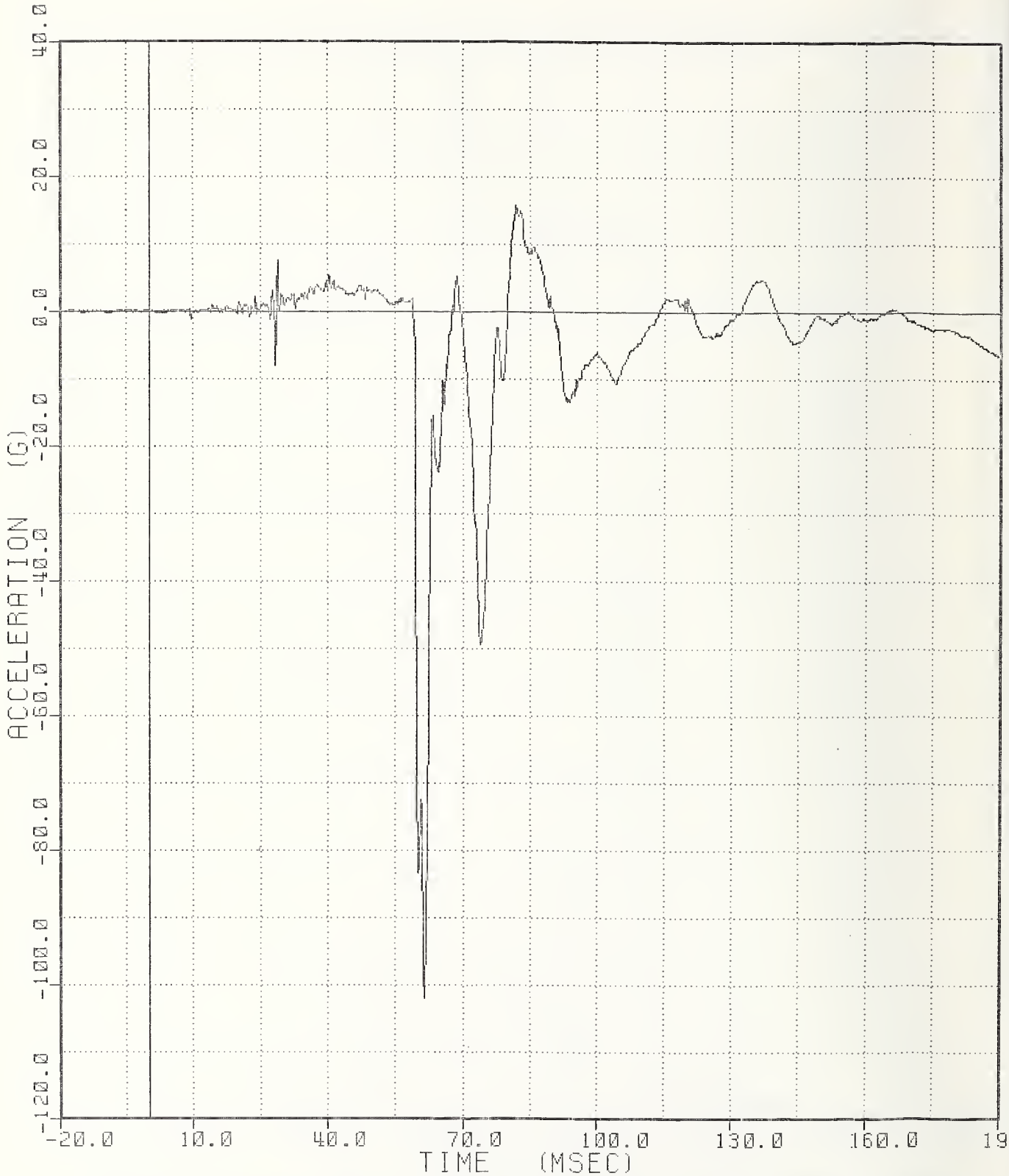
SRL66-1 VERTICAL HEAD ACCELERATION

SRL661 VRTC SRL66 - 1 83342 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = 0.025 @ -20.0000 165.882 @ 61.7500



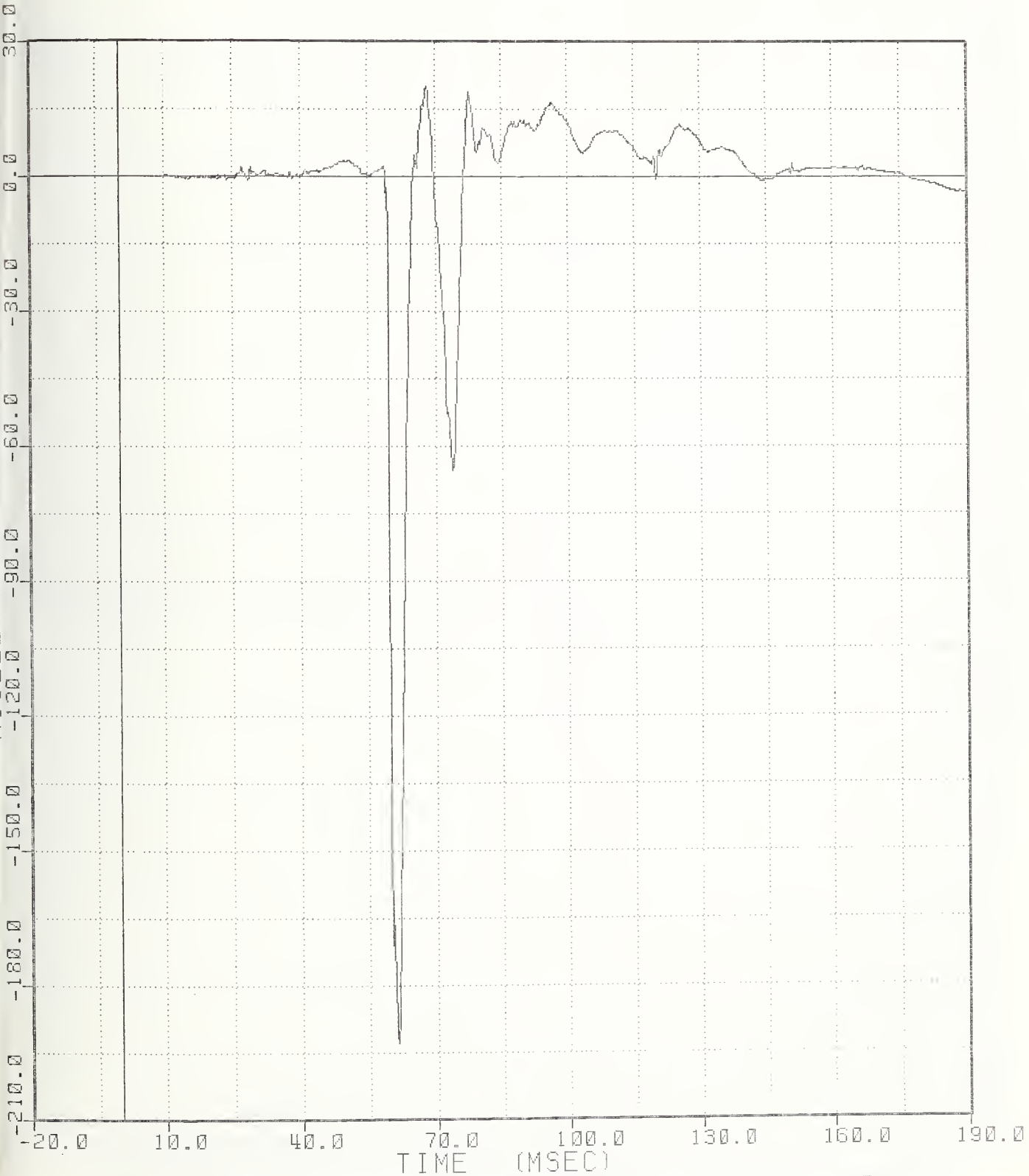
SRL66-1 RESULTANT HEAD ACCELERATION

SRL662 VRTC SRL66 - 2 83346 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -101.926 @ 61.5000 15.734 @ 82.1250



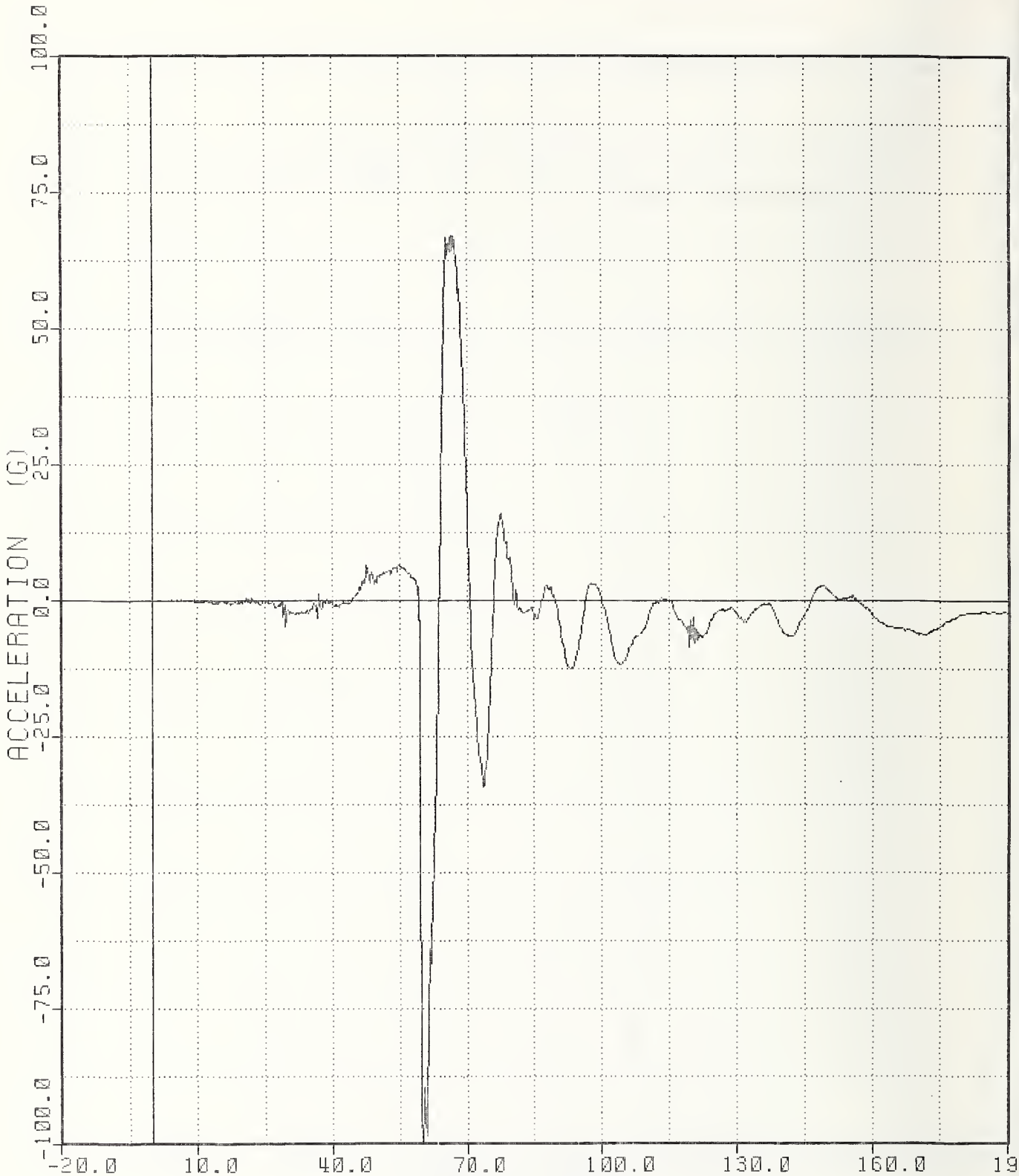
SRL66-2 LONGITUDINAL HEAD ACCELERATION

SRL662 VRTC SRL66 - 2 83346 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -192.963 @ 61.3750 20.166 @ 68.2500



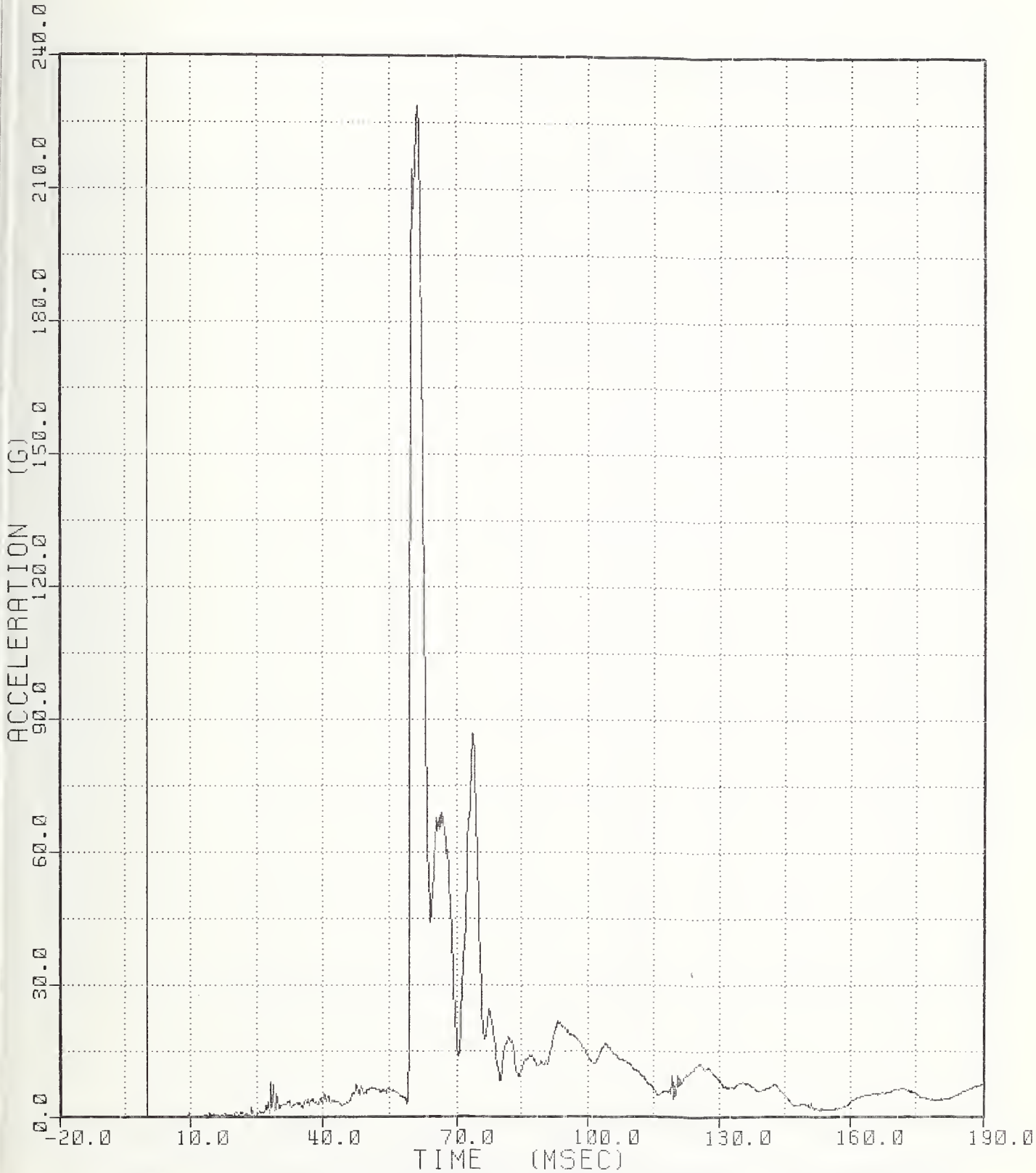
SRL66-2 LATERAL HEAD ACCELERATION

SRL662 VRTC SRL66 - 2 83346 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -100.091 @ 60.0000 67.118 @ 67.1250



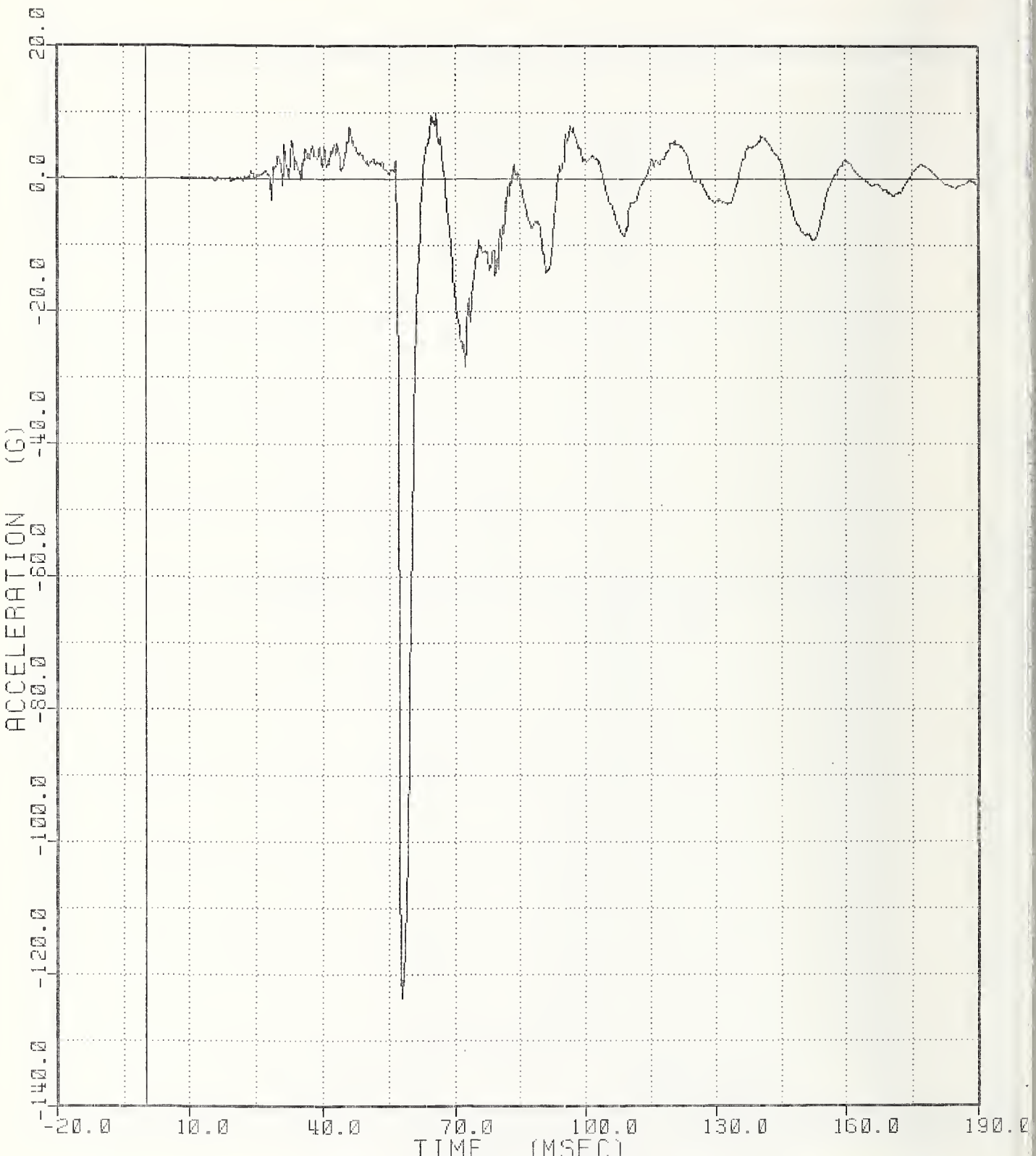
SRL66-2 VERTICAL HEAD ACCELERATION

SRL662 VRTC SRL66 - 2 83346 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = 0.042 @ -20.0000 228.848 @ 61.3750



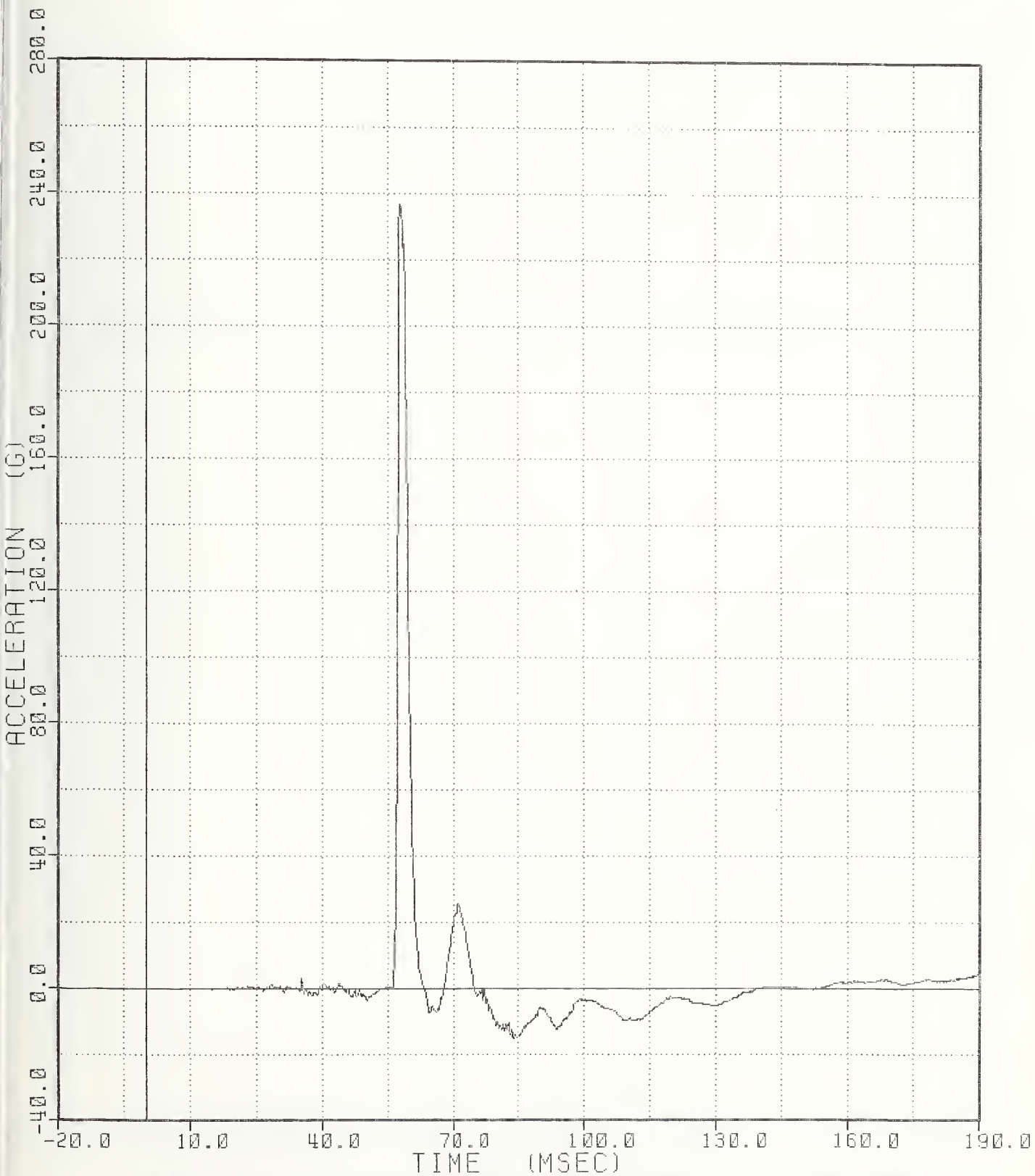
SRL66-2 RESULTANT HEAD ACCELERATION

SRL663 VRTC SRL66 - 3 83349 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -123.516 @ 57.8750 9.912 @ 65.6250



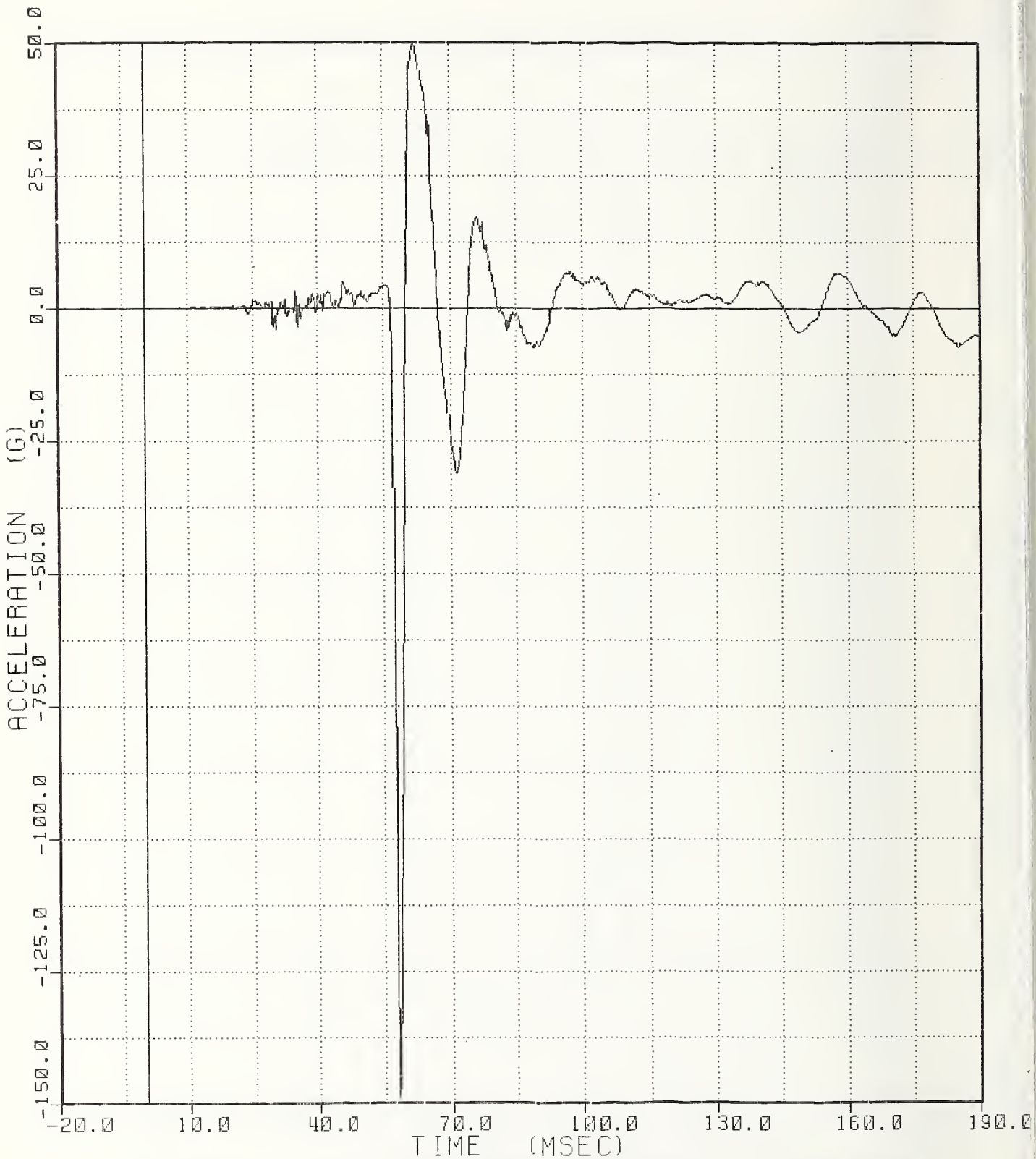
SRL66-3 LONGITUDINAL HEAD ACCELERATION

SRL663 VRTC SRL66 - 3 83349 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -15.268 @ 84.0000 236.707 @ 57.7500



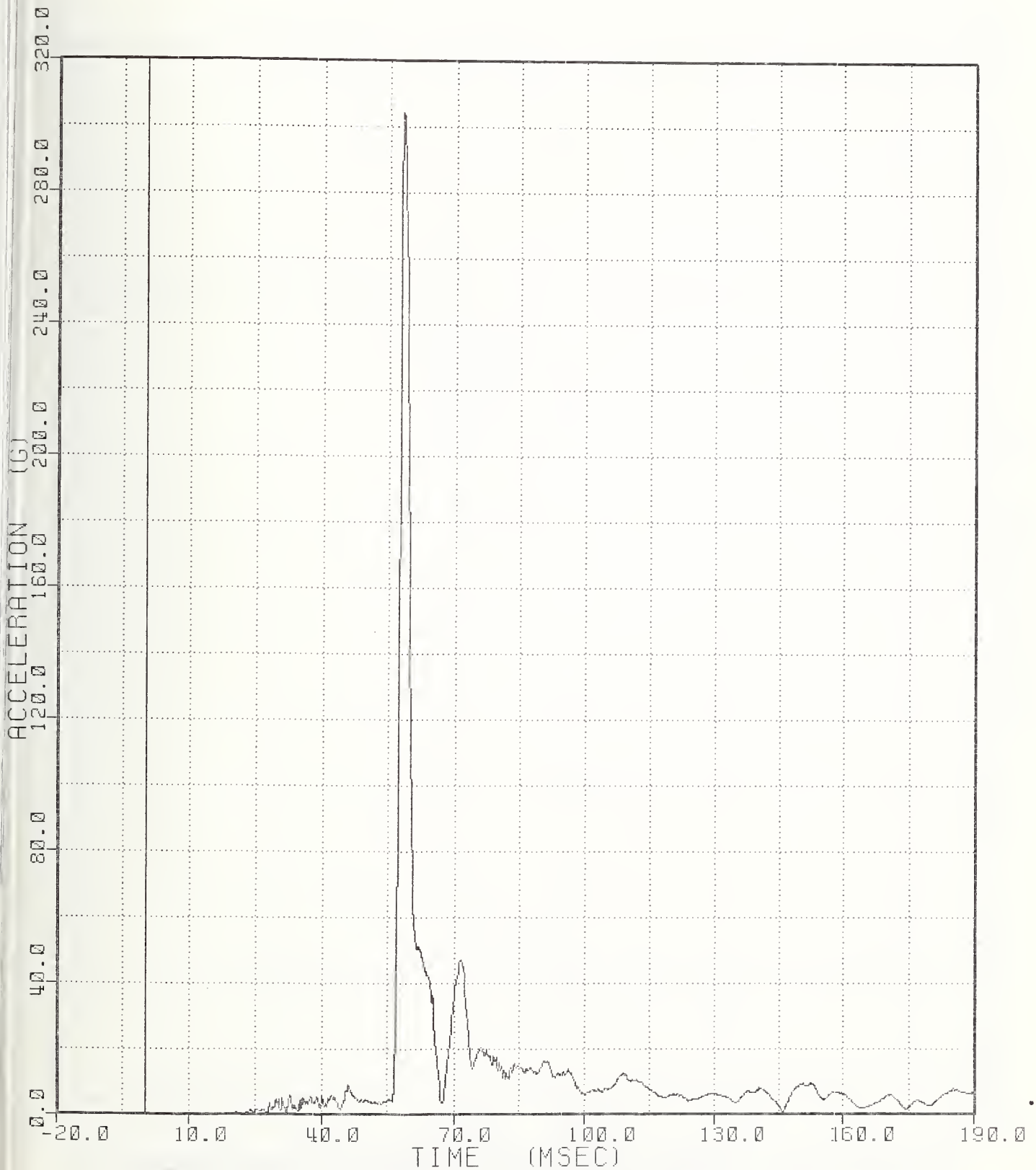
SRL66-3 LATERAL HEAD ACCELERATION

SRL663 VRTC SRL66 - 3 83349 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -149.002 @ 57.7500 49.892 @ 62.1250



SRL66-3 VERTICAL HEAD ACCELERATION

SRL663 VRTC SRL66 - 3 83349 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = 0.057 @ -19.7500 304.246 @ 57.7500

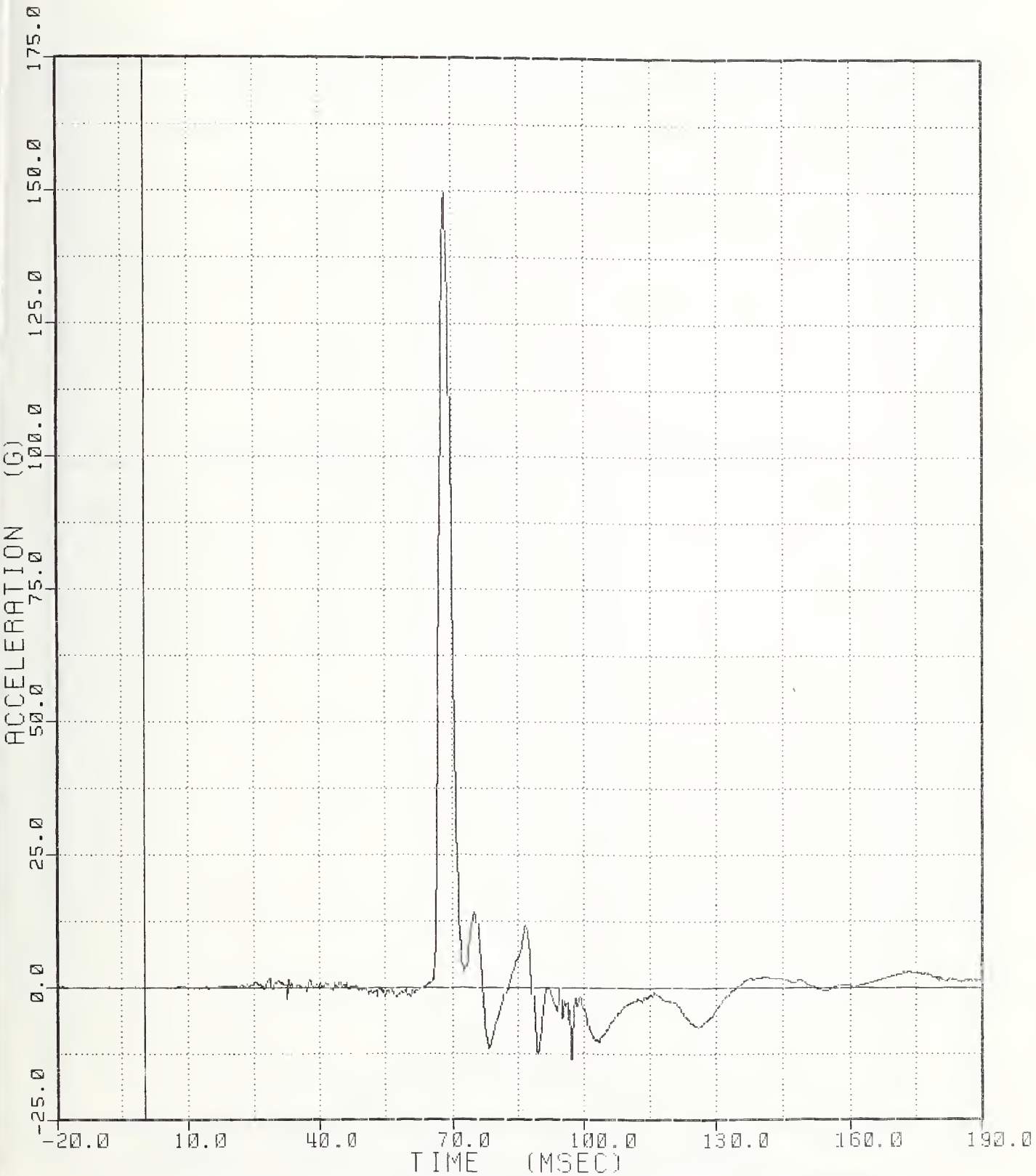


SRL66-3 RESULTANT HEAD ACCELERATION

SRL664 VRTC SRL66 - 4 83353 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -84.254 @ 68.8750 6.639 @ 78.8750

SRL66-4 LONGITUDINAL HEAD ACCELERATION

SRL664 VRTC SRL66 - 4 83353 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -13.624 @ 97.2500 149.791 @ 68.7500

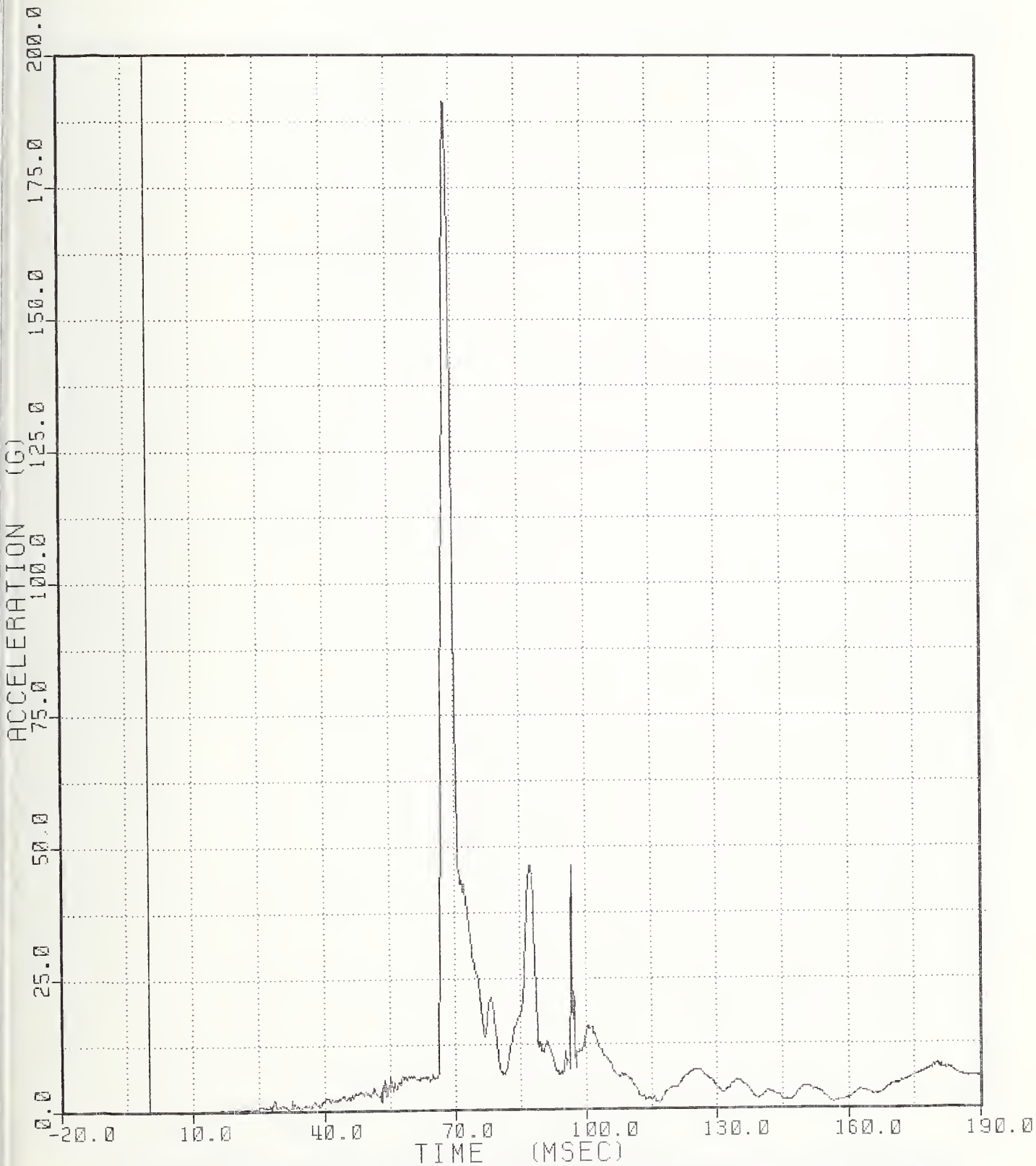


SRL66-4 LATERAL HEAD ACCELERATION

SRL664 VRTC SRL66 - 4 83353 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = -93.972 @ 68.3750 45.336 @ 96.8750

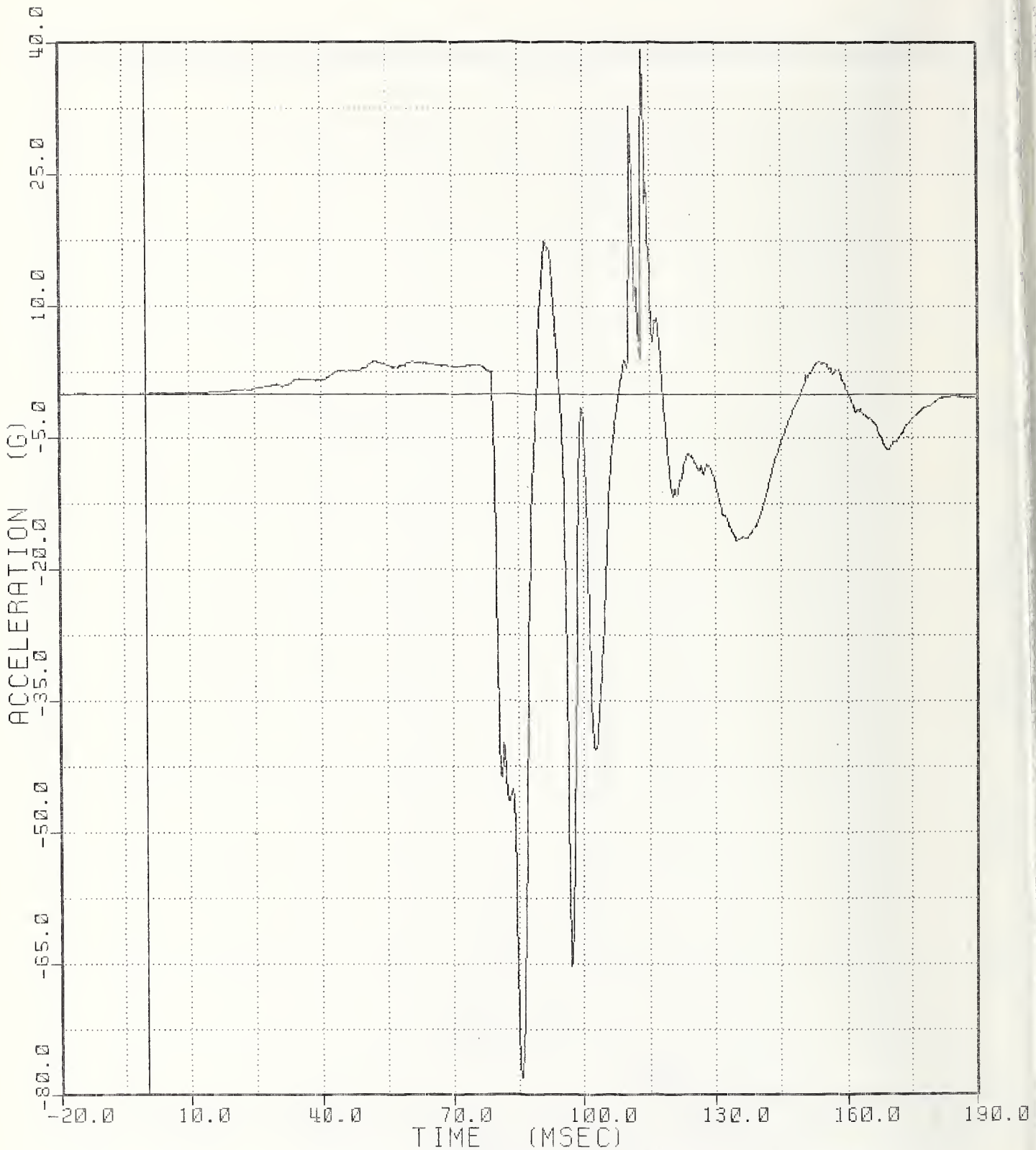
SRL66-4 VERTICAL HEAD ACCELERATION

SRL664 VRTC SRL66 - 4 83353 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 0.0 MPH
MIN, MAX VALUES = 0.068 @ -13.0000 191.219 @ 68.5000



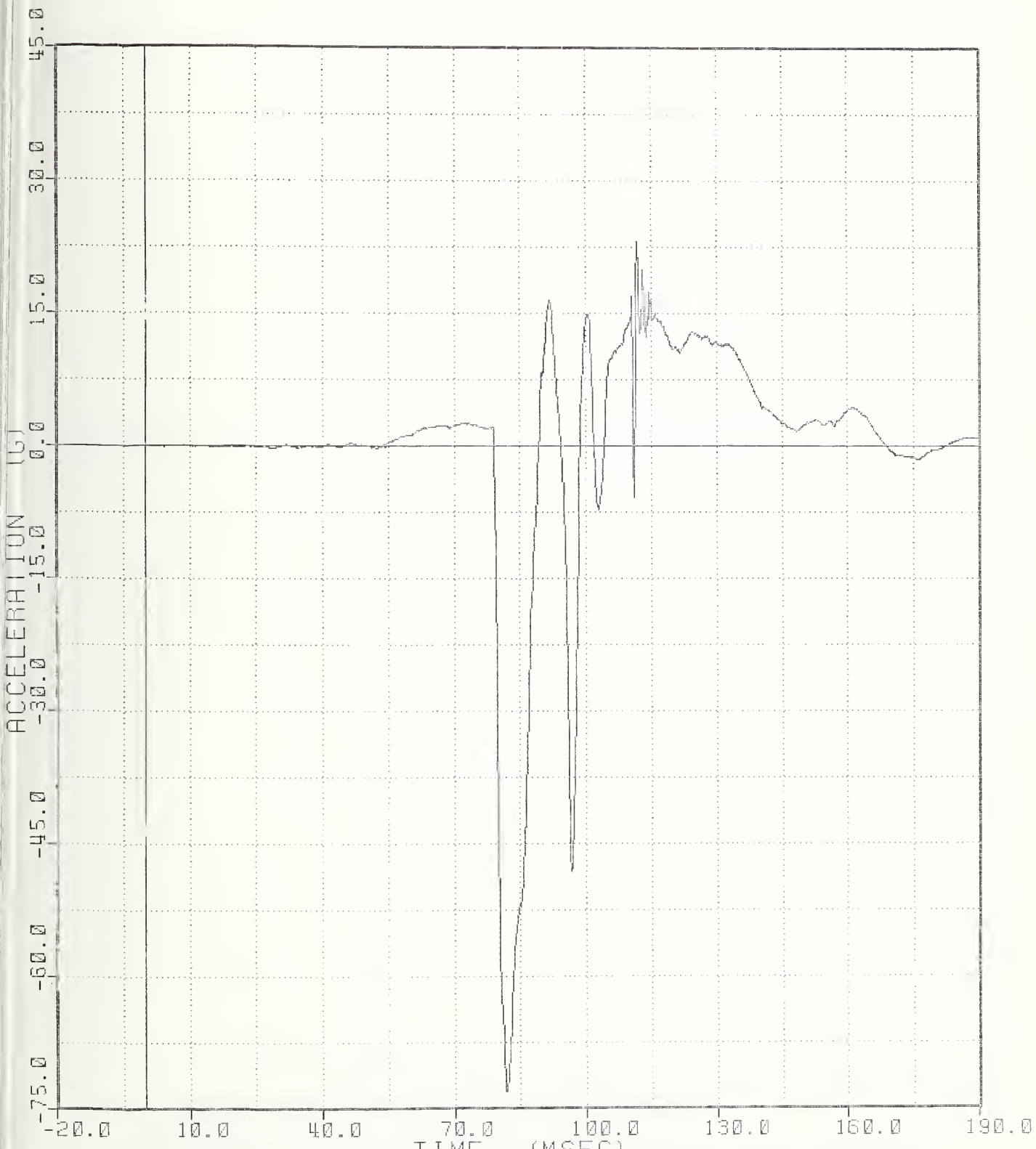
SRL66-4 RESULTANT HEAD ACCELERATION

SRL665 VRTC SRL66-5 84039 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 19.7 MPH
MIN, MAX VALUES = -78.090 @ 85.6250 39.242 @ 113.2500



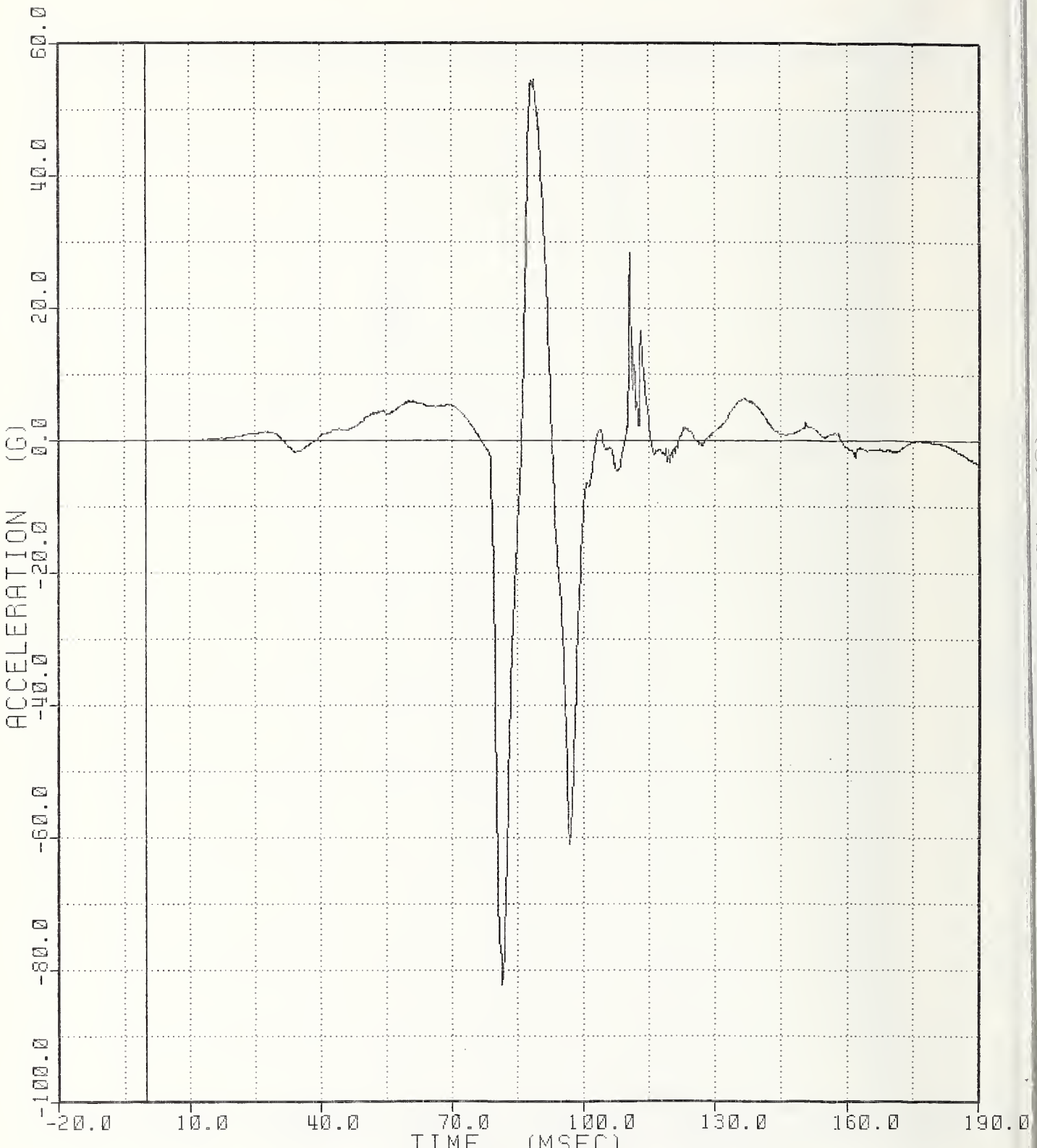
SRL66-5 LONGITUDINAL HEAD ACCELERATION

SRL665 VRTC SRL66-5 84039 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 19.7 MPH
MIN, MAX VALUES = -73.009 @ 81.7500 23.048 @ 111.7500



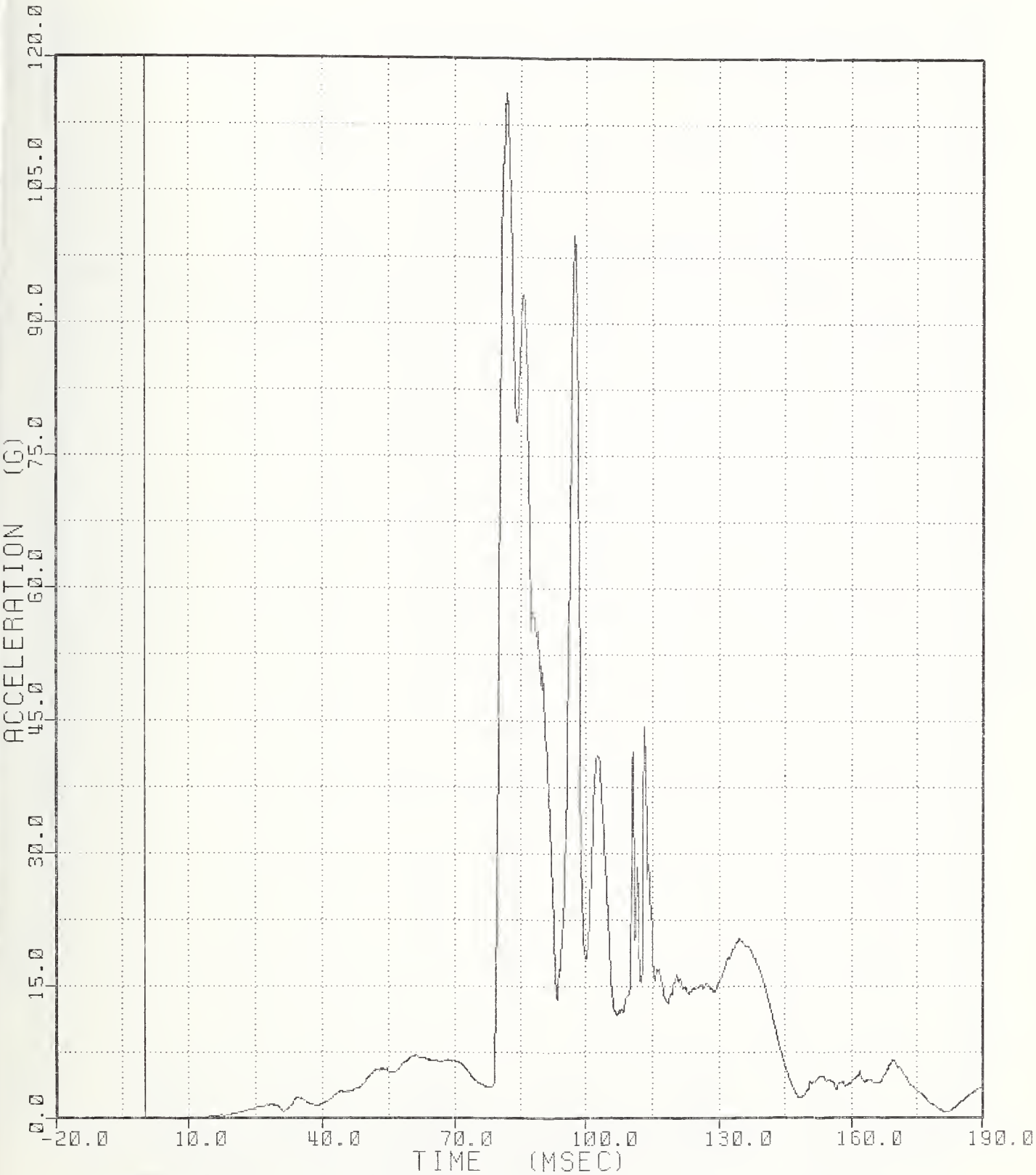
SRL66-5 LATERAL HEAD ACCELERATION

SRL665 VRTC SRL66-5 84039 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 19.7 MPH
MIN, MAX VALUES = -82.229 @ 81.5000 54.627 @ 88.7500



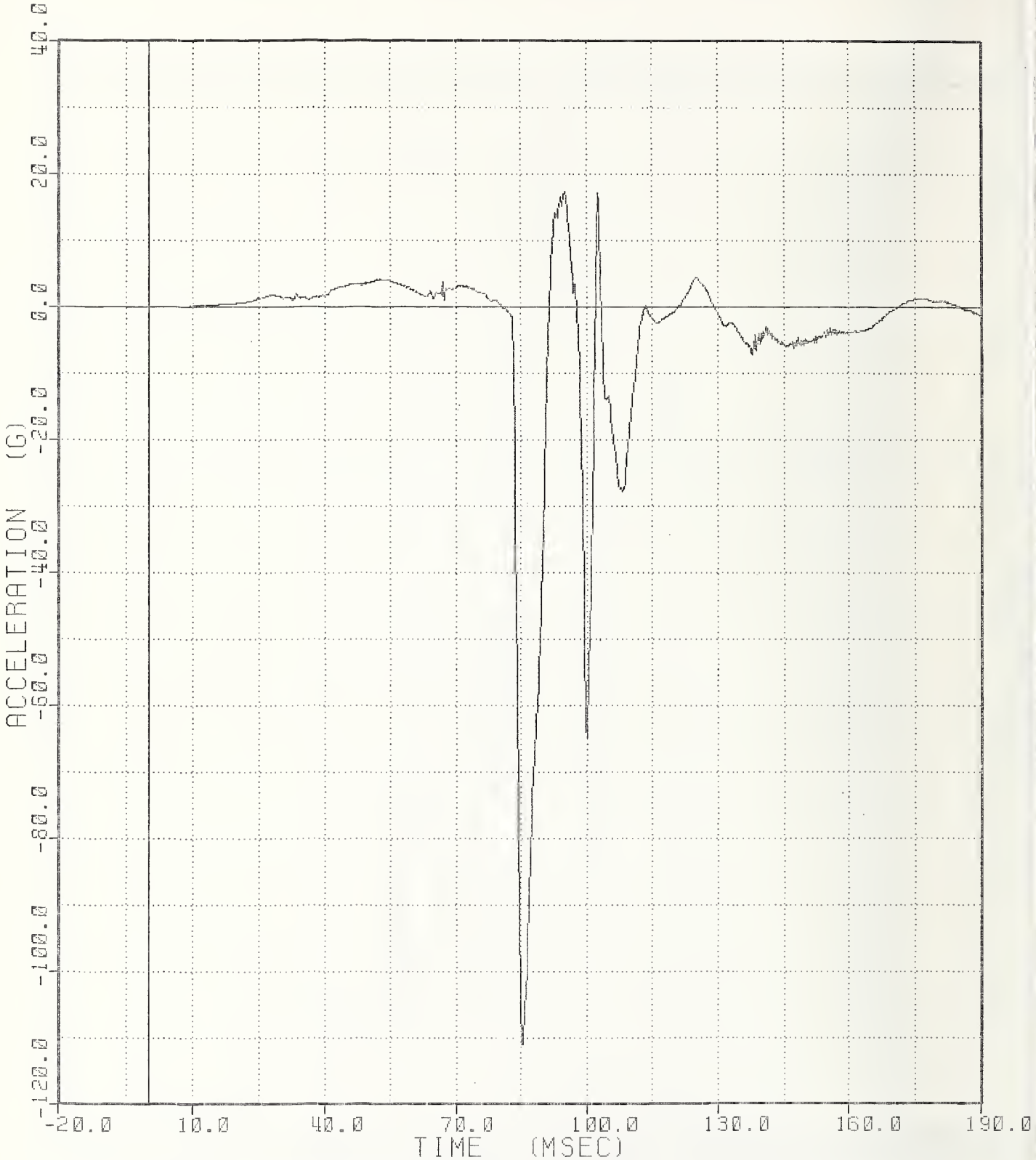
SRL66-5 VERTICAL HEAD ACCELERATION

SRL665 VRTC SRL66-5 84039 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 19.7 MPH
MIN, MAX VALUES = 0.027 @ -20.0000 116.147 @ 81.7500



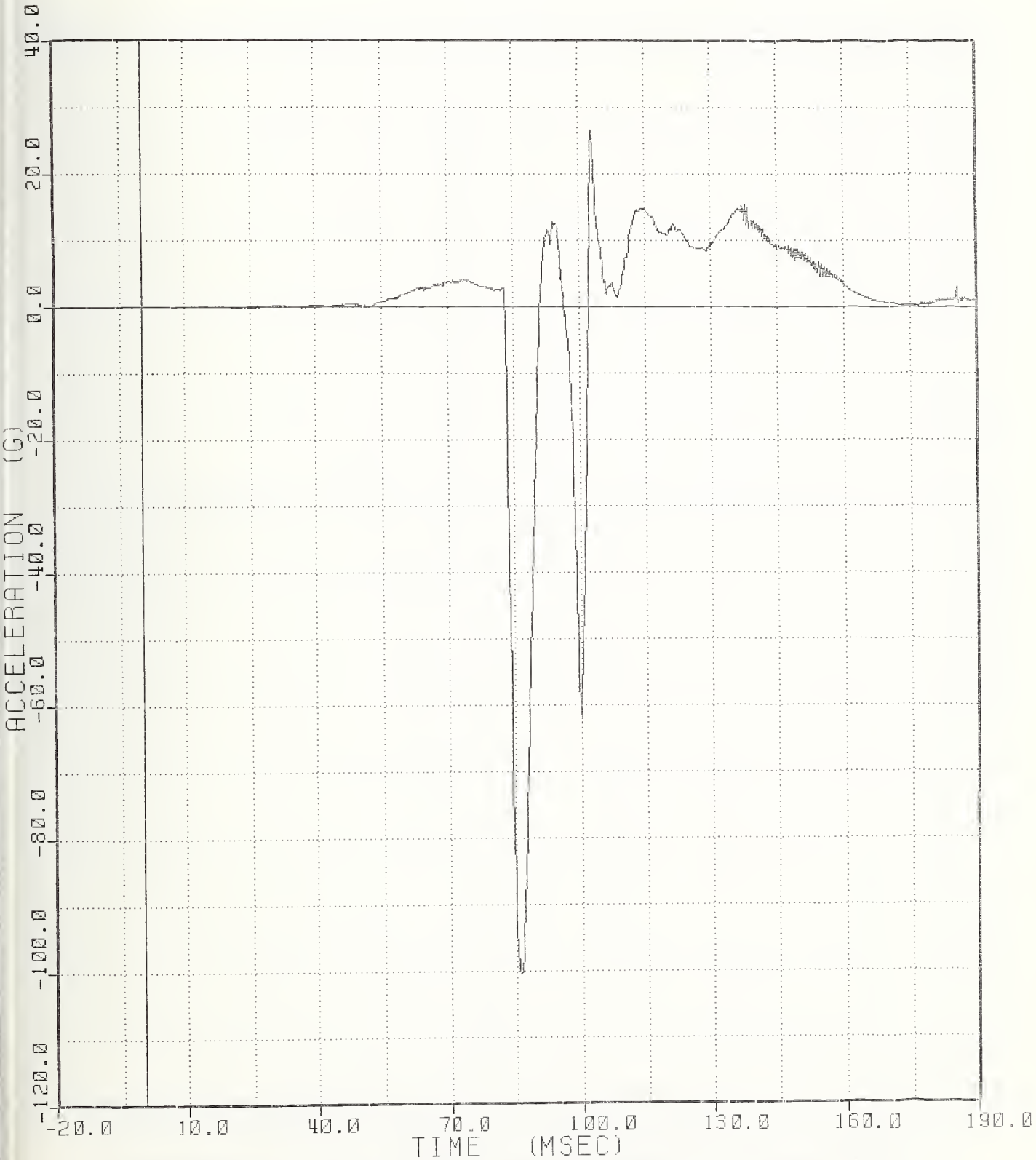
SRL66-5 RESULTANT HEAD ACCELERATION

SRL666 VRTC SRL66-6 84040 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 20.0 MPH
MIN, MAX VALUES = -111.097 @ 85.5000 17.413 @ 95.0000



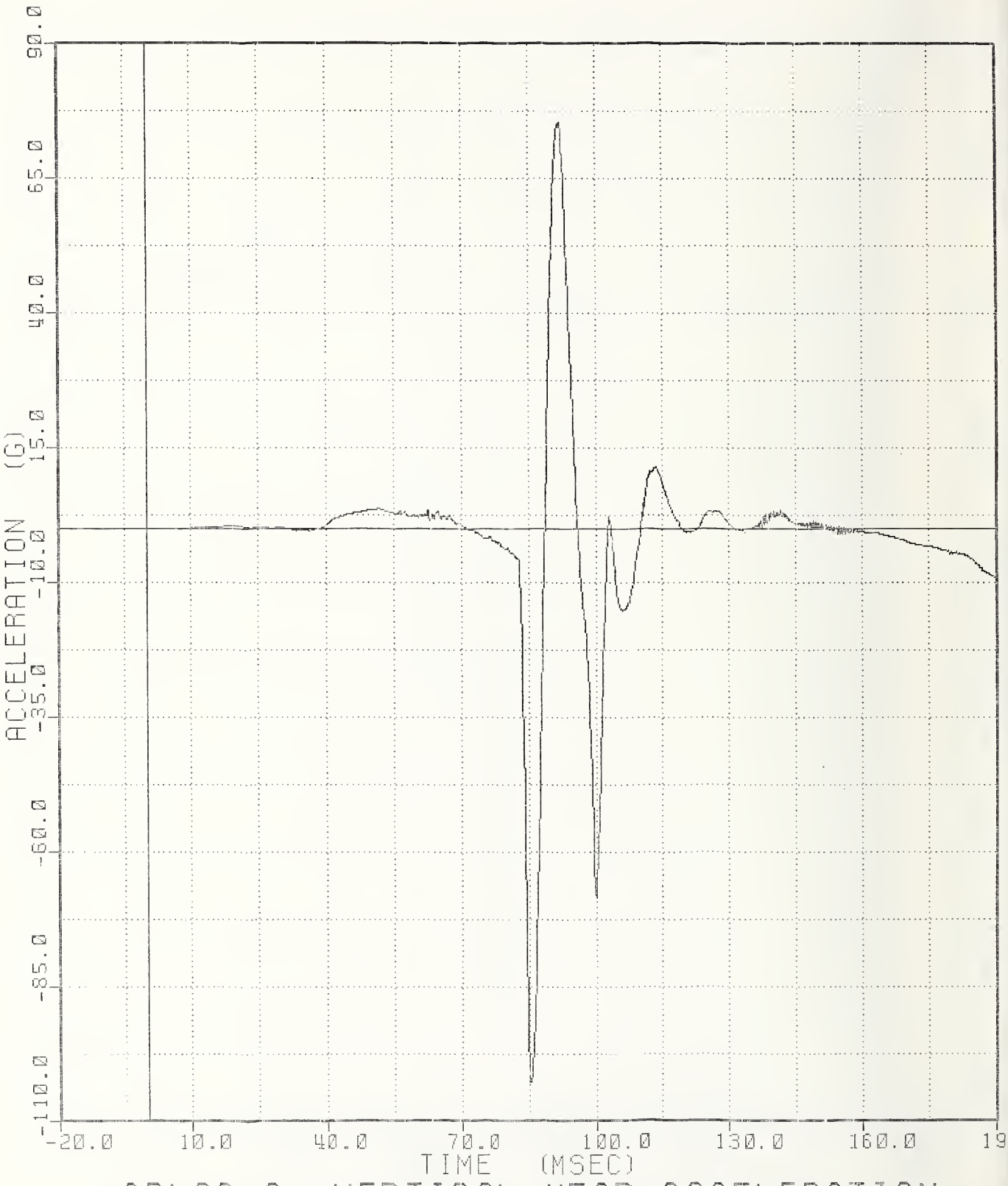
SRL66-6 LONGITUDINAL HEAD ACCELERATION

SRL666 VRTC SRL66-6 84040 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 20.0 MPH
MIN, MAX VALUES = -100.312 @ 86.0000 26.610 @ 103.0000



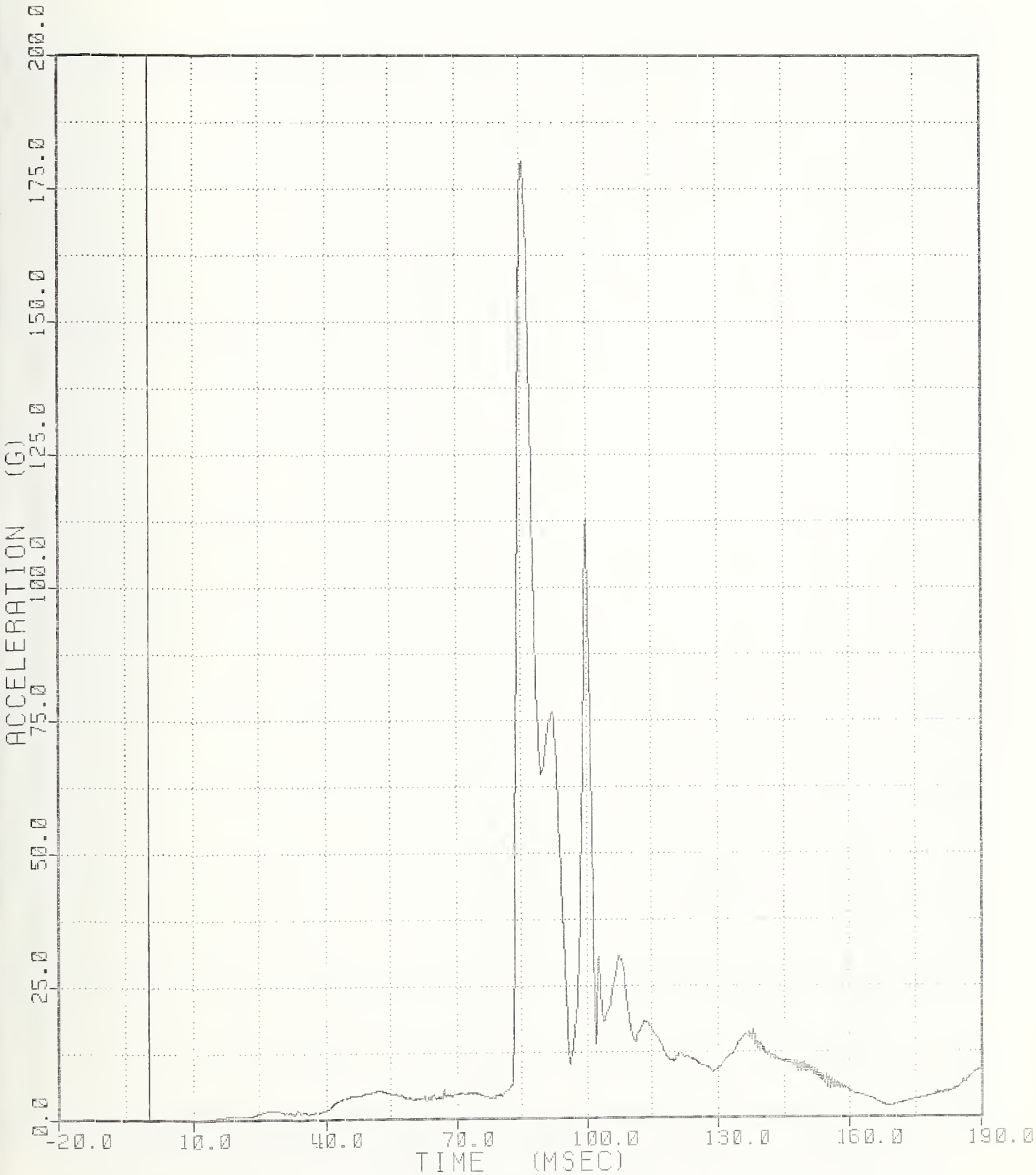
SRL66-6 LATERAL HEAD ACCELERATION

SRL666 VRTC SRL66-6 84040 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 20.0 MPH
MIN, MAX VALUES = -102.837 @ 85.1250 75.516 @ 92.1250



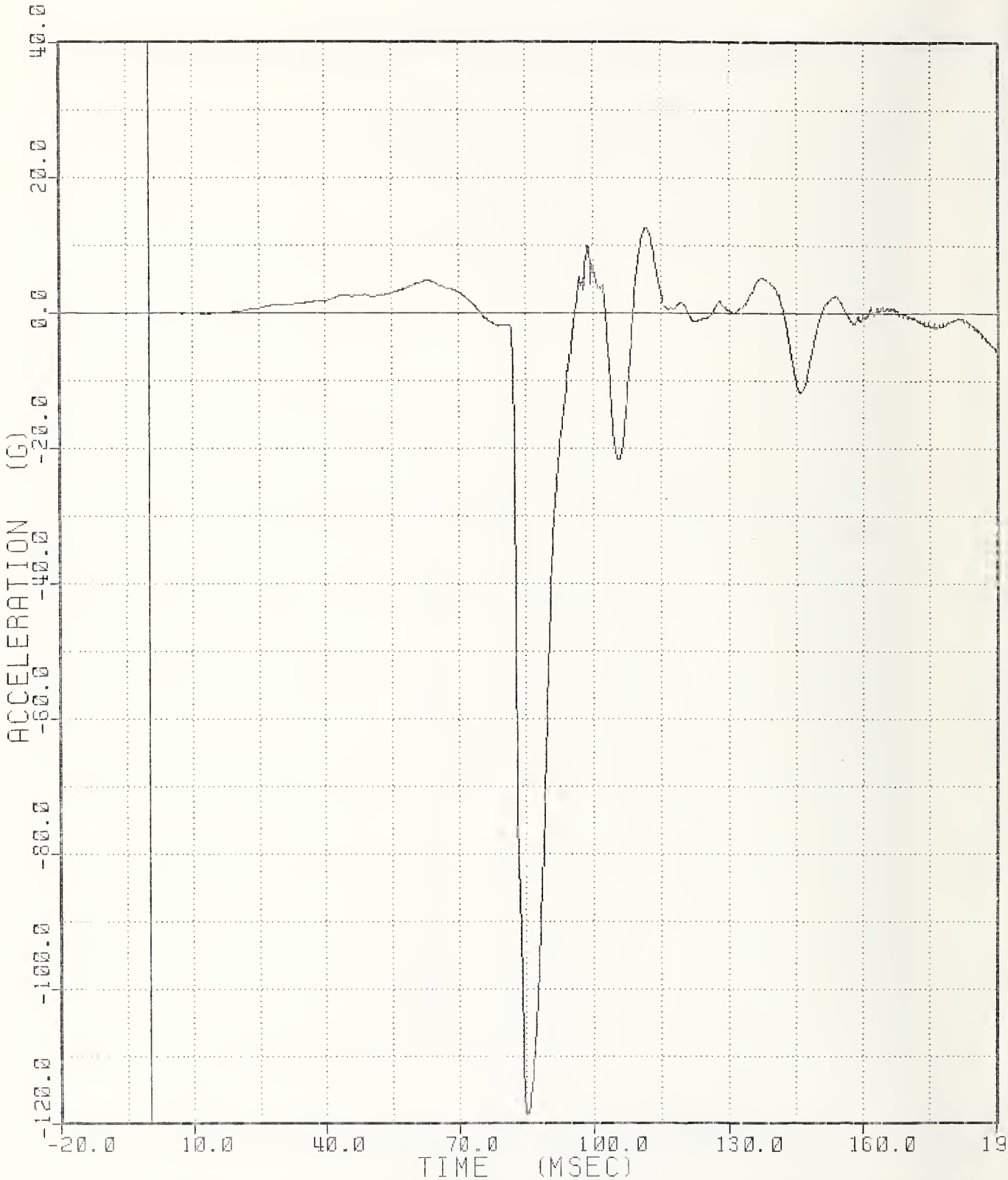
SRL66-6 VERTICAL HEAD ACCELERATION

SRL666 VRTC SRL66-6 84040 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 20.0 MPH
MIN, MAX VALUES = 0.027 @ -19.8750 180.163 @ 85.5000



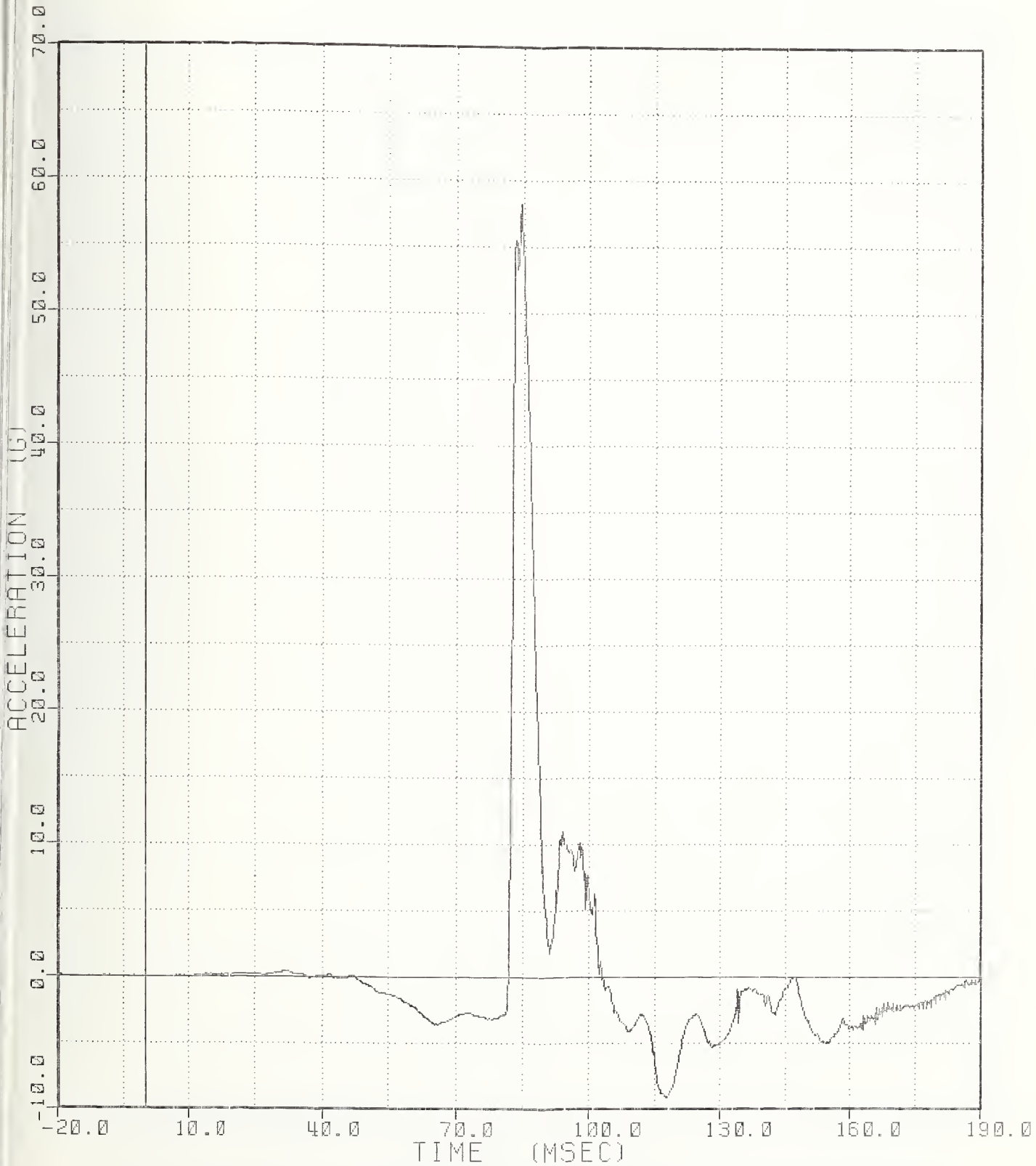
SRL66-6 RESULTANT HEAD ACCELERATION

SRL667 VRTC SRL66-7 84041 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 20.9 MPH
MIN, MAX VALUES = -118.599 @ 85.3750 12.677 @ 111.7500



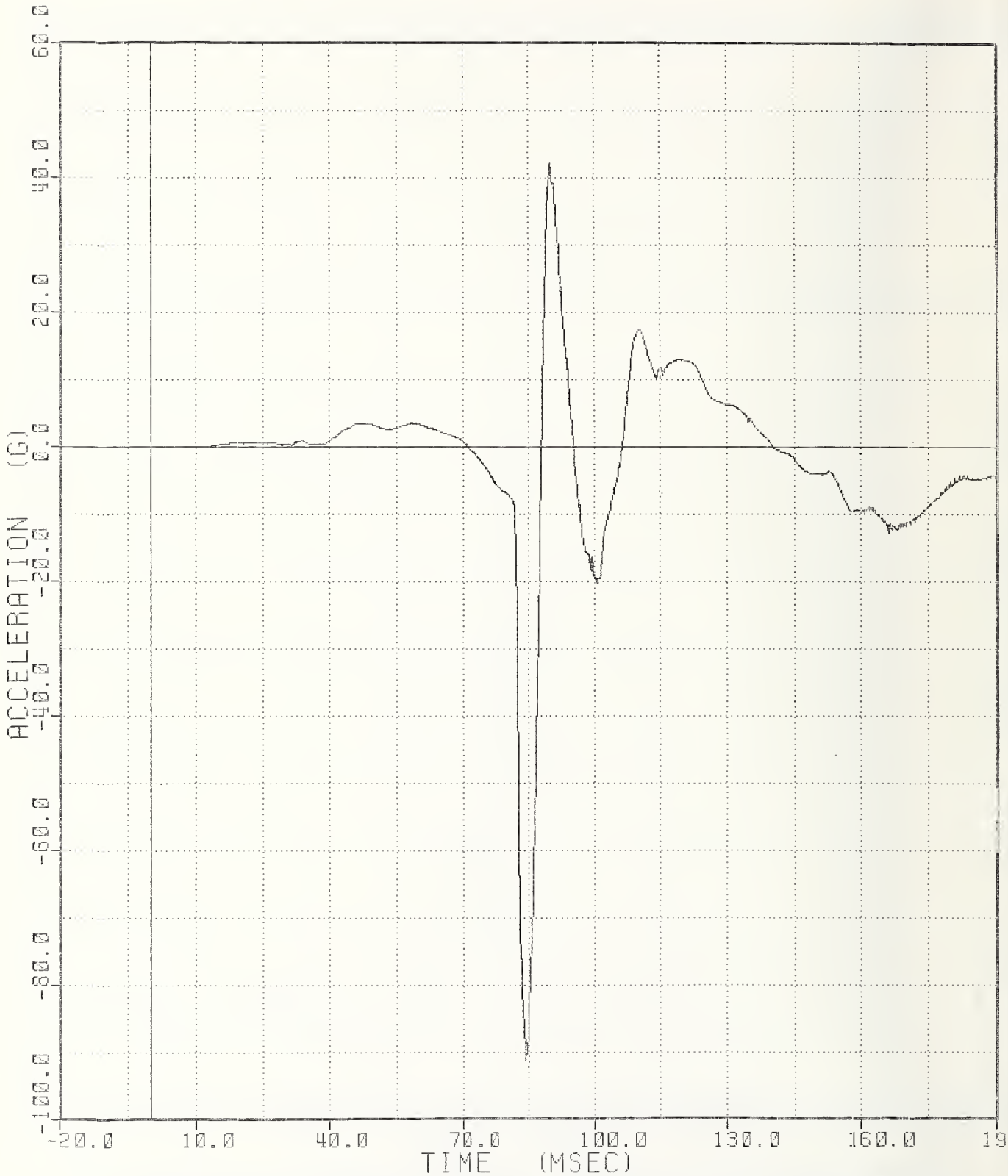
SRL66-7 LONGITUDINAL HEAD ACCELERATION

SRL667 VRTC SRL66-7 84041 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 20.9 MPH
MIN, MAX VALUES = -9.084 @ 117.7500 58.199 @ 84.2500



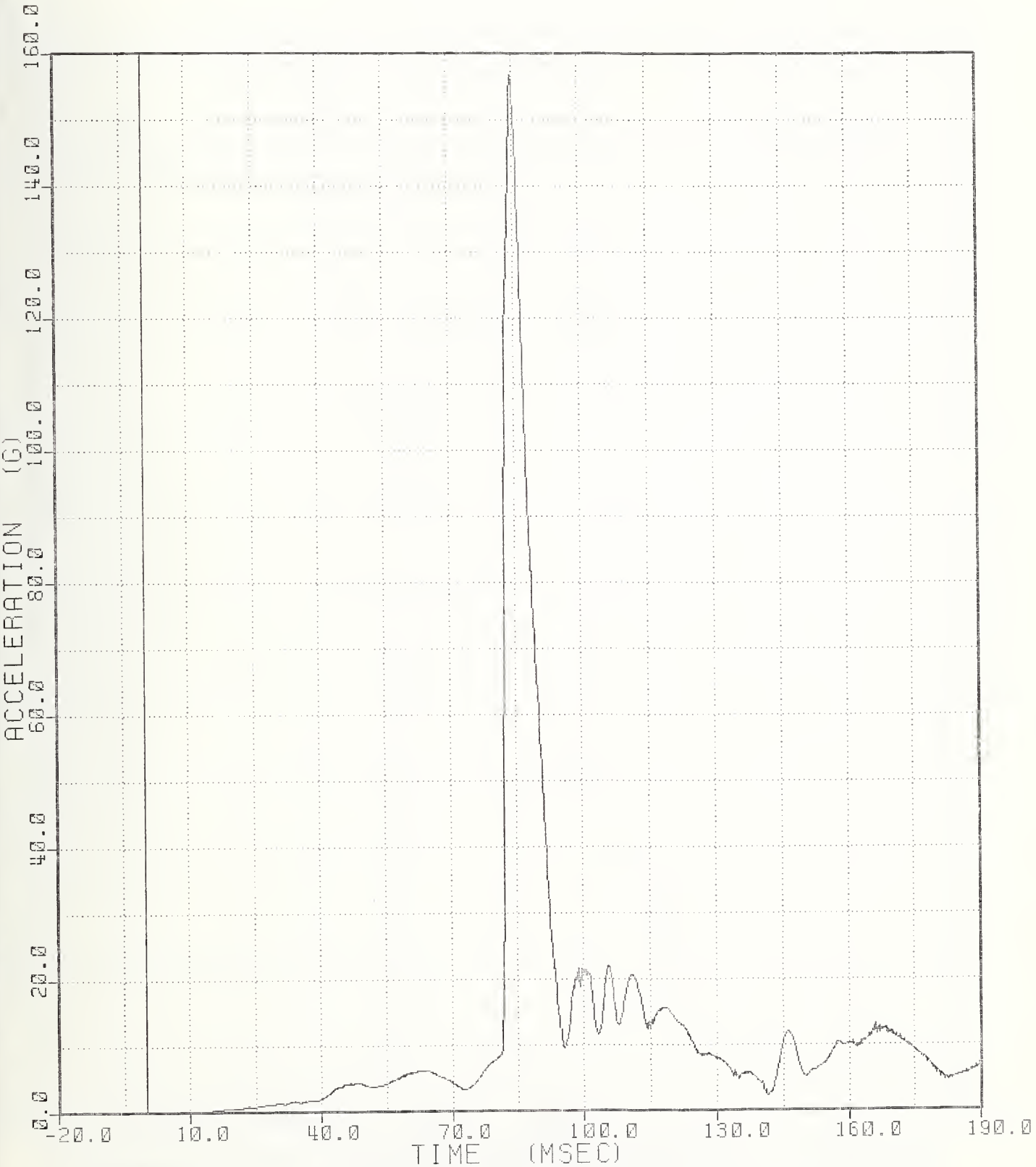
SRL66-7 LATERAL HEAD ACCELERATION

SRL667 VRTC SRL66-7 84041 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 20.9 MPH
MIN, MAX VALUES = -91.117 @ 84.3750 42.170 @ 90.1250



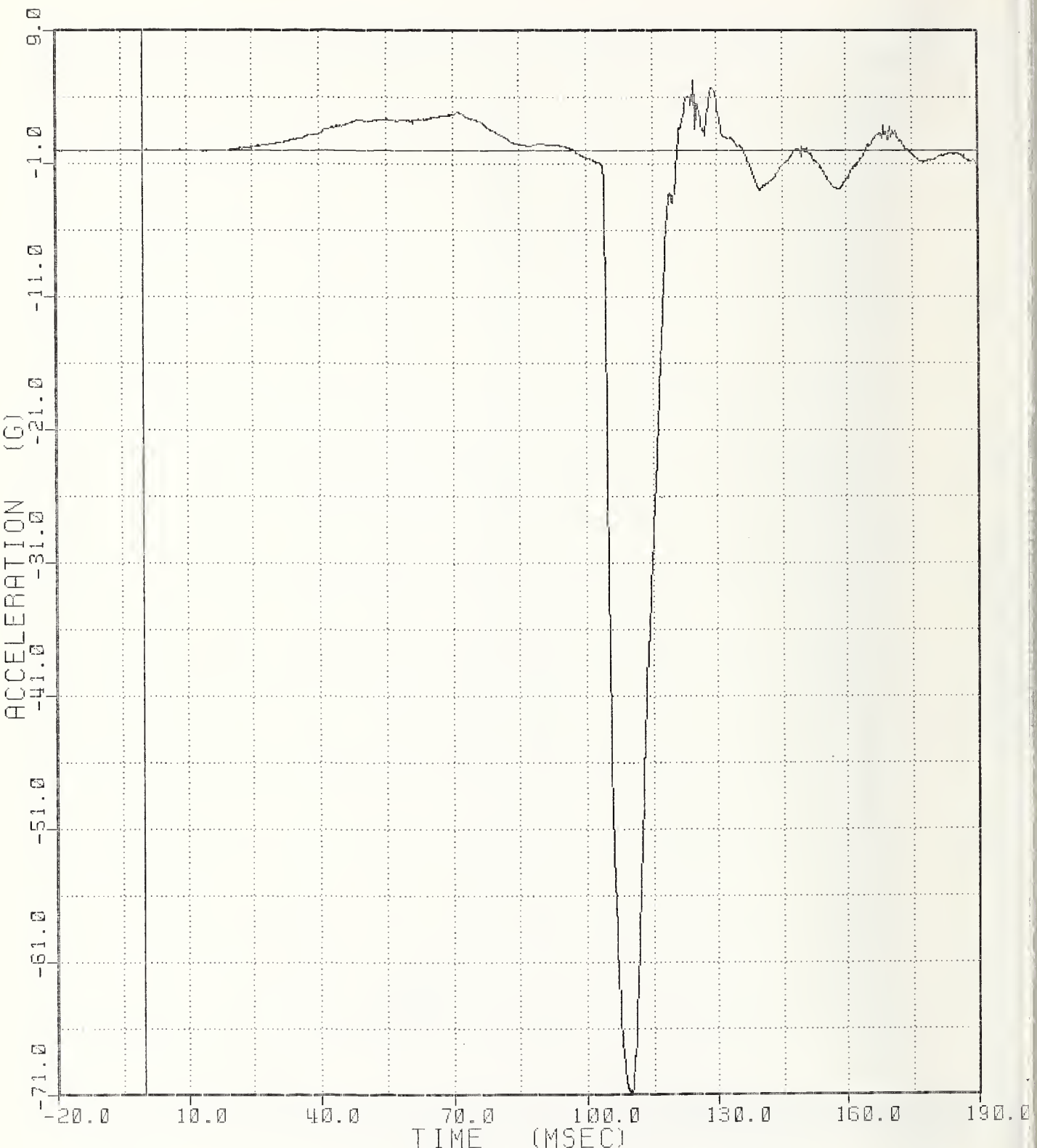
SRL66-7 VERTICAL HEAD ACCELERATION

SRL667 VRTC SRL66-7 84041 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 20.9 MPH
MIN, MAX VALUES = 0.017 @ -20.0000 156.724 @ 84.7500



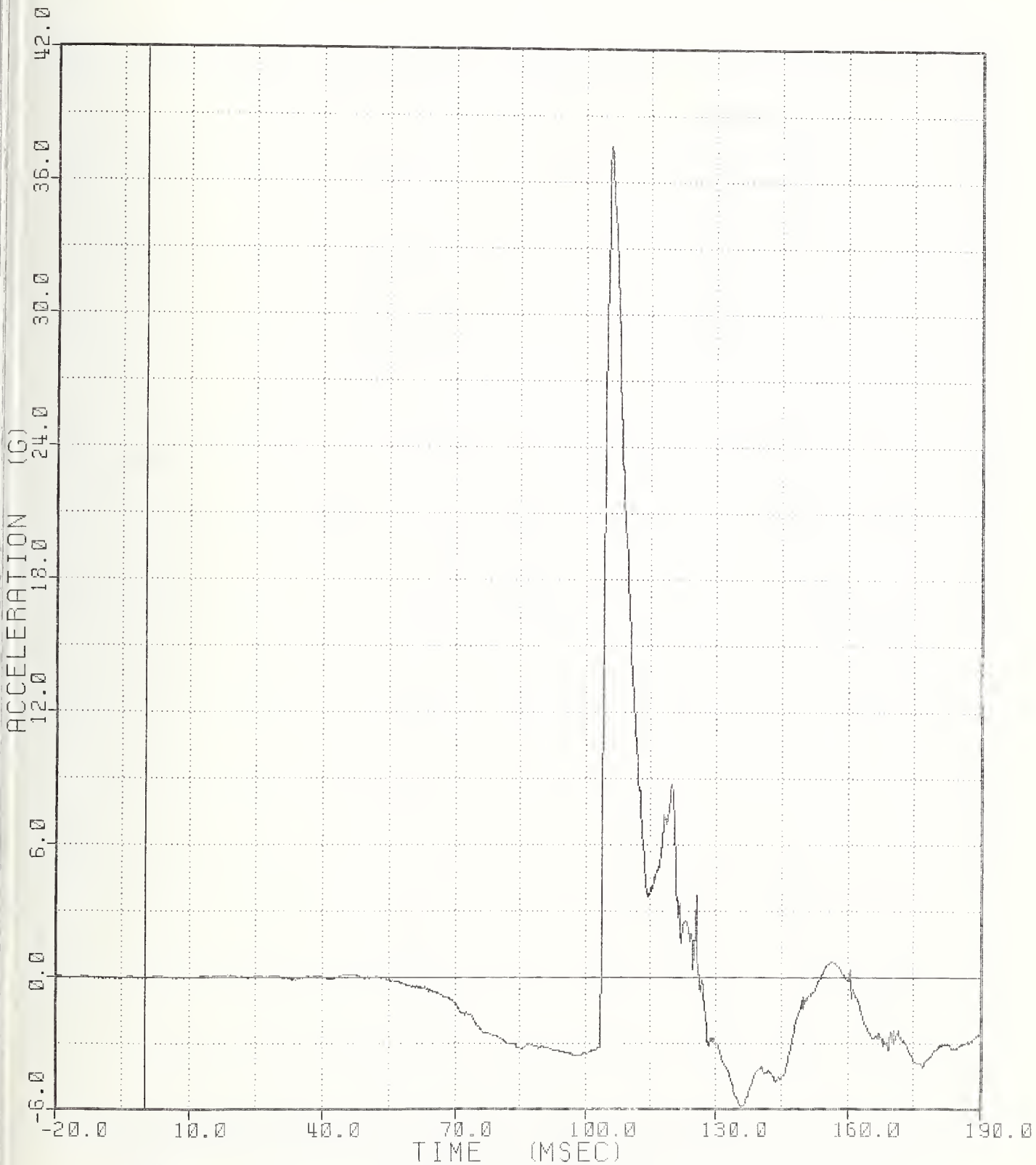
SRL66-7 RESULTANT HEAD ACCELERATION

SRL668 VRTC SRL66-8 84044 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 15.2 MPH
MIN, MAX VALUES = -70.980 @ 110.2500 5.251 @ 124.6250



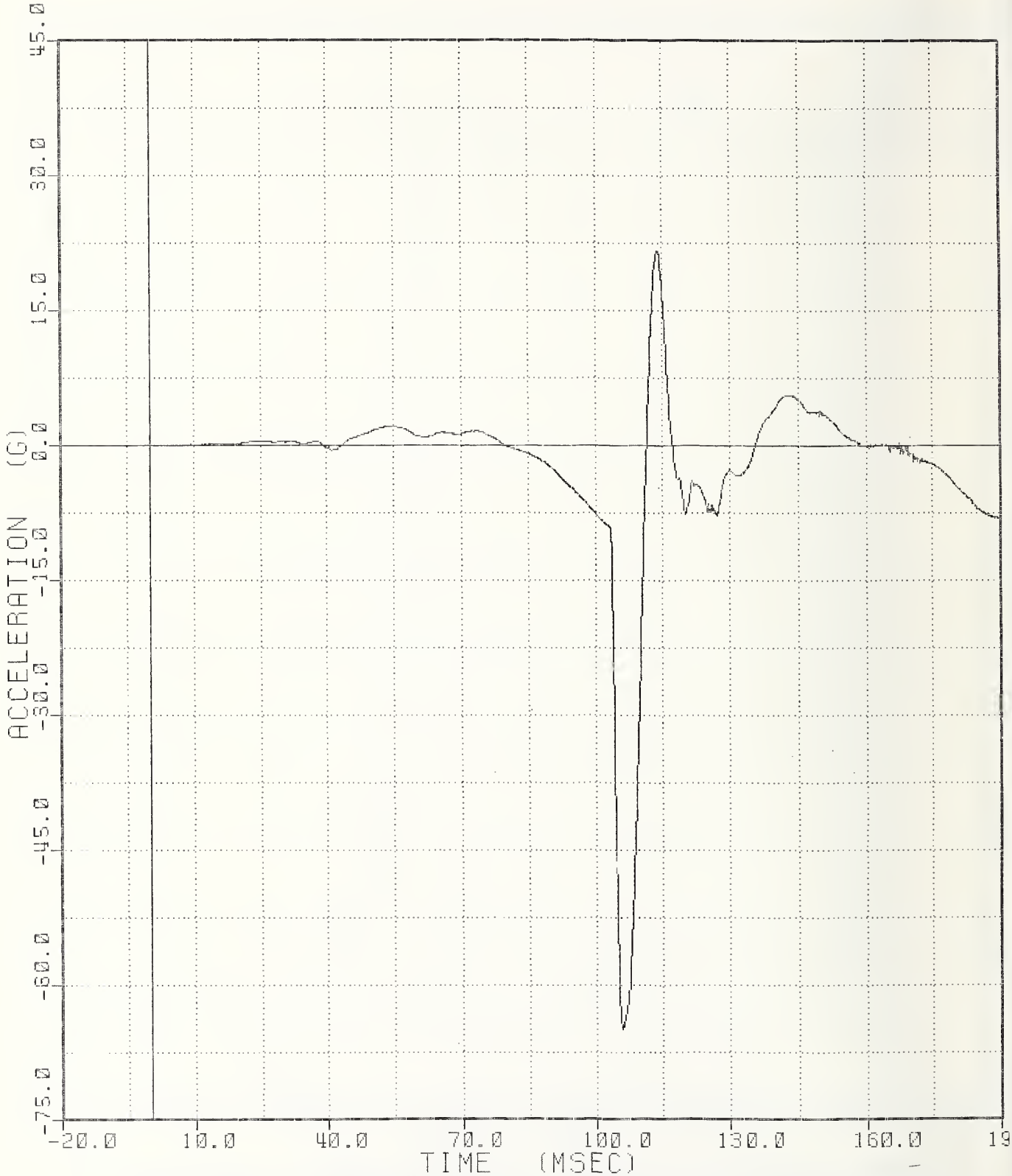
SRL66-8 LONGITUDINAL HEAD ACCELERATION

SRL668 VRTC SRL66-8 84044 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 15.2 MPH
MIN, MAX VALUES = -5.863 @ 136.0000 37.600 @ 105.7500



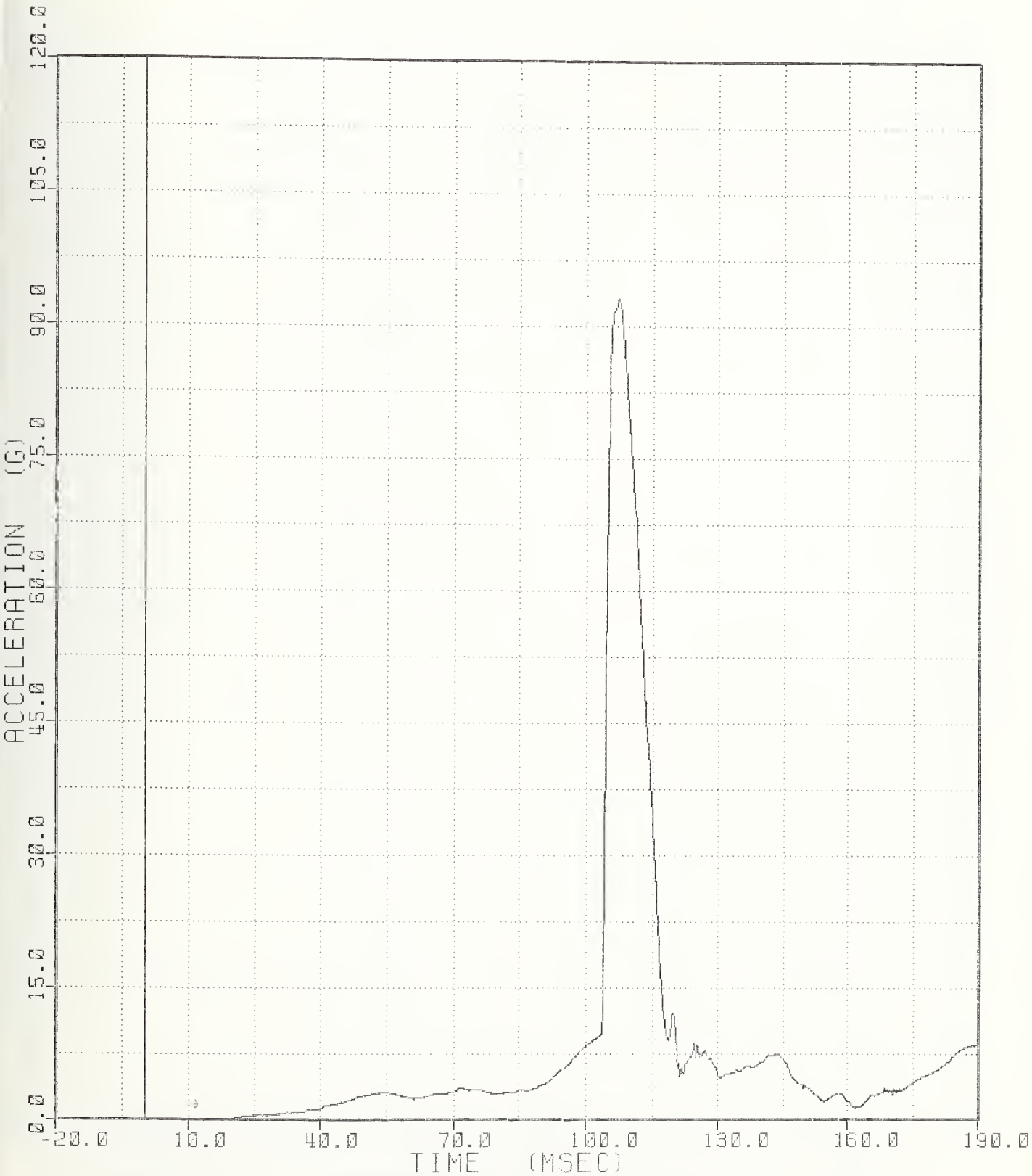
SRL66-8 LATERAL HEAD ACCELERATION

SRL668 VRTC SRL66-8 84044 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 15.2 MPH
MIN, MAX VALUES = -64.987 @ 106.1250 21.613 @ 113.8750



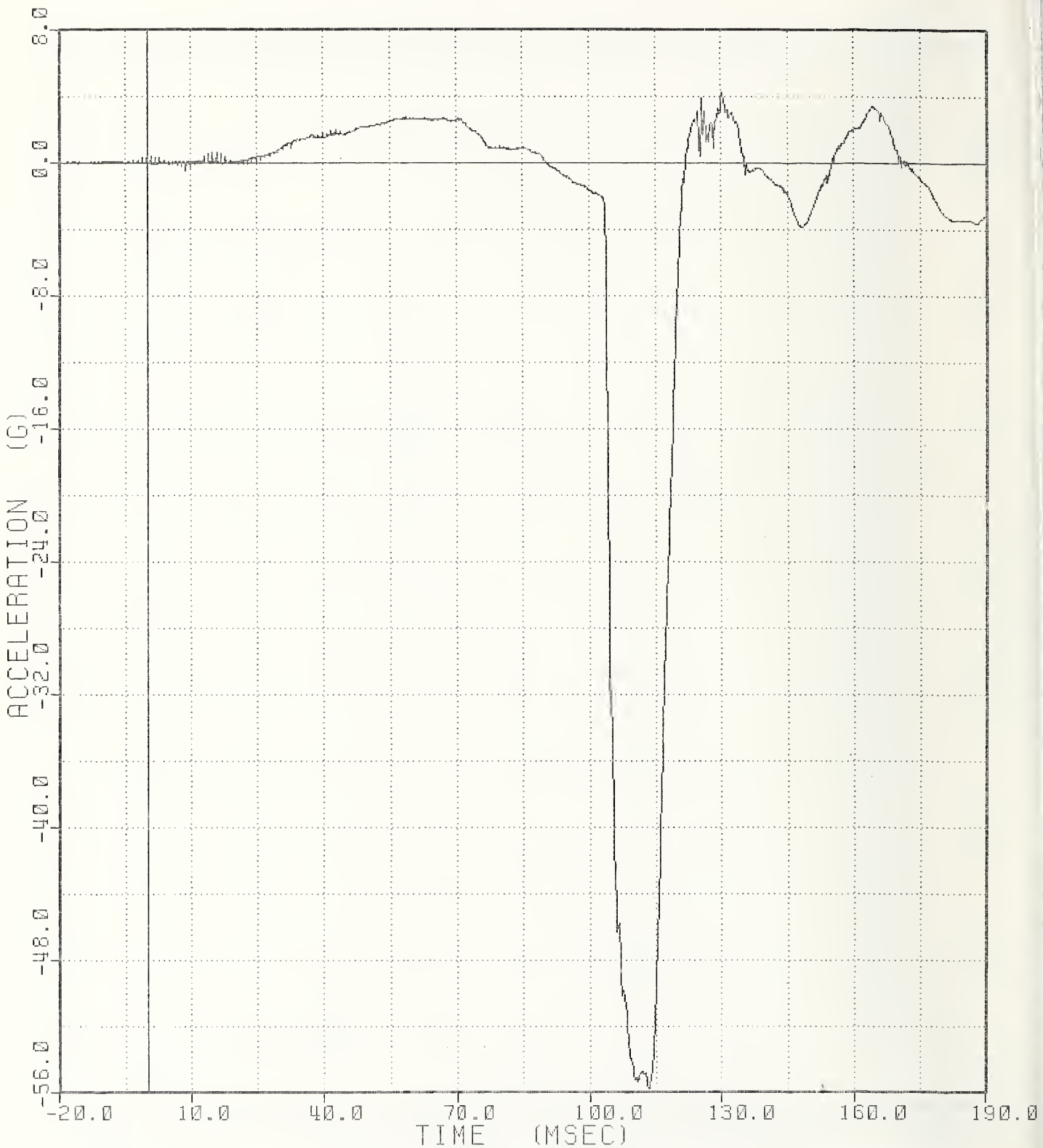
SRL66-8 VERTICAL HEAD ACCELERATION

SRL668 VRTC SRL66-8 84044 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 15.2 MPH
MIN, MAX VALUES = 0.019 @ -19.7500 93.201 @ 107.1250



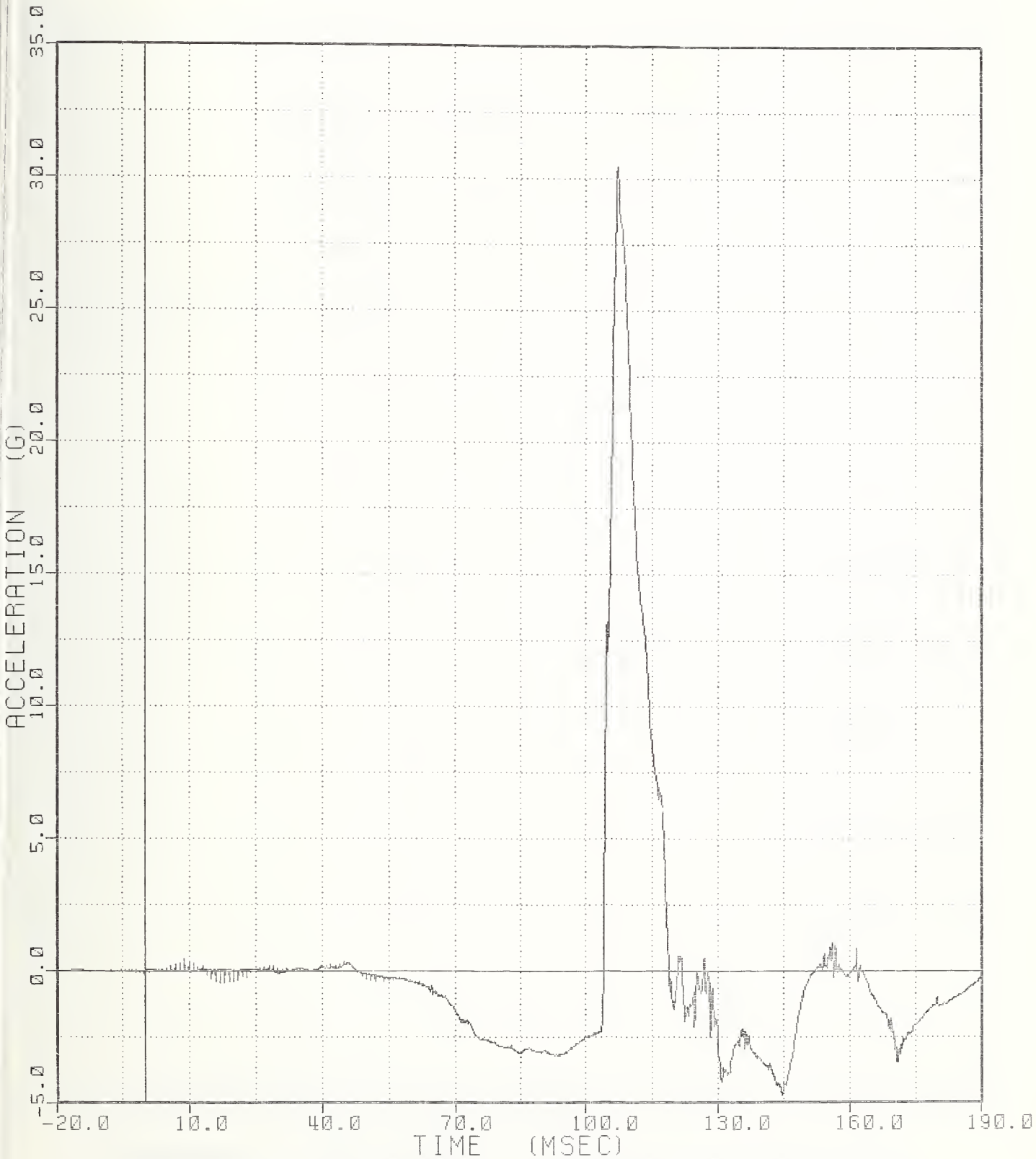
SRL66-8 RESULTANT HEAD ACCELERATION

SRL669 VRTC SRL66-9 84045 10-JUL-84 11:41:15
HEDXG1 FILTER = ALPF 1650/ 5214/ -40 15.1 MPH
MIN, MAX VALUES = -55.735 @ 113.2500 4.238 @ 130.2500



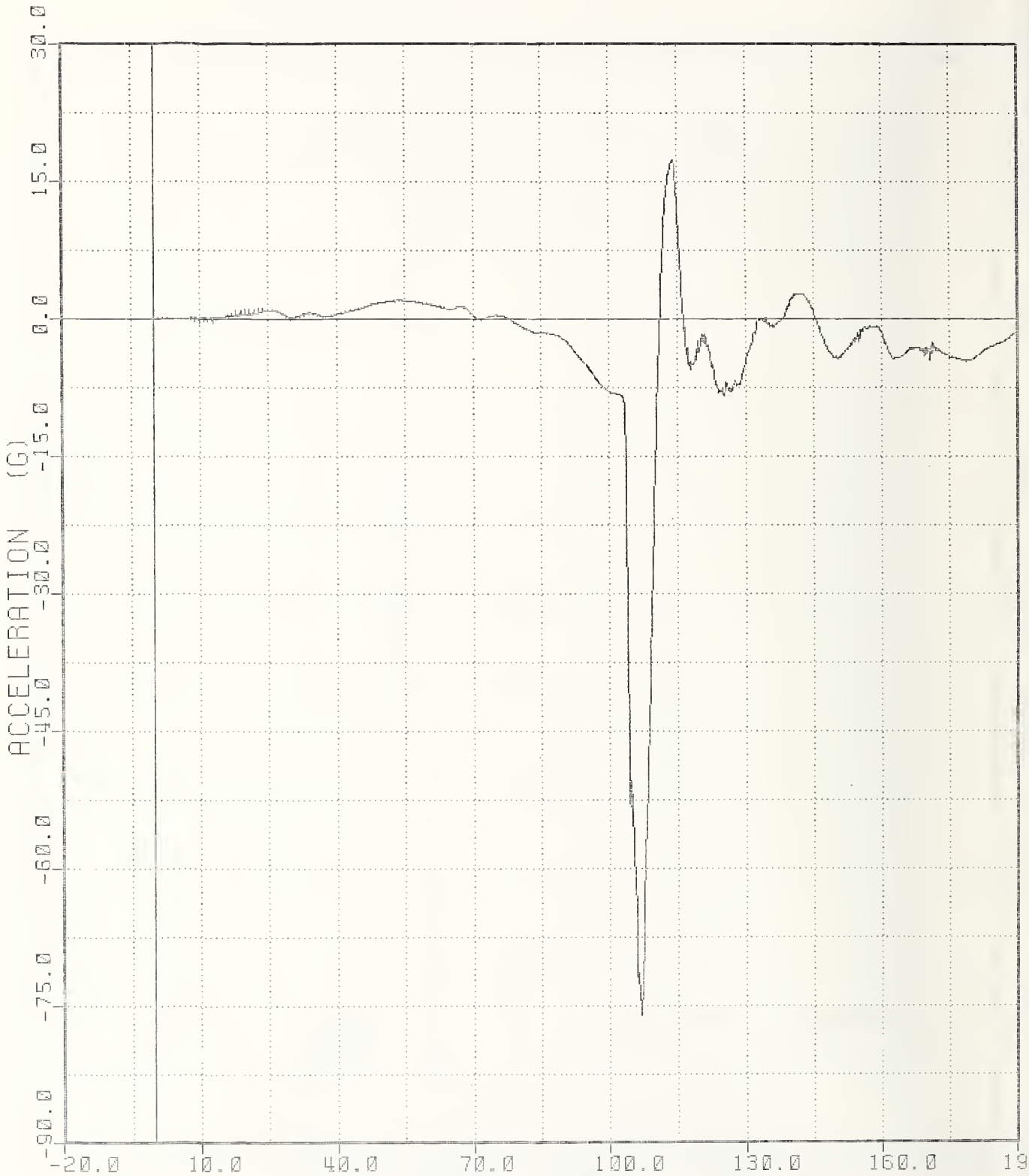
SRL66-9 LONGITUDINAL HEAD ACCELERATION

SRL669 VRTC SRL66-9 84045 10-JUL-84 11:41:15
HEDYG1 FILTER = ALPF 1650/ 5214/ -40 15.1 MPH
MIN, MAX VALUES = -4.703 @ 144.7500 30.441 @ 107.1250



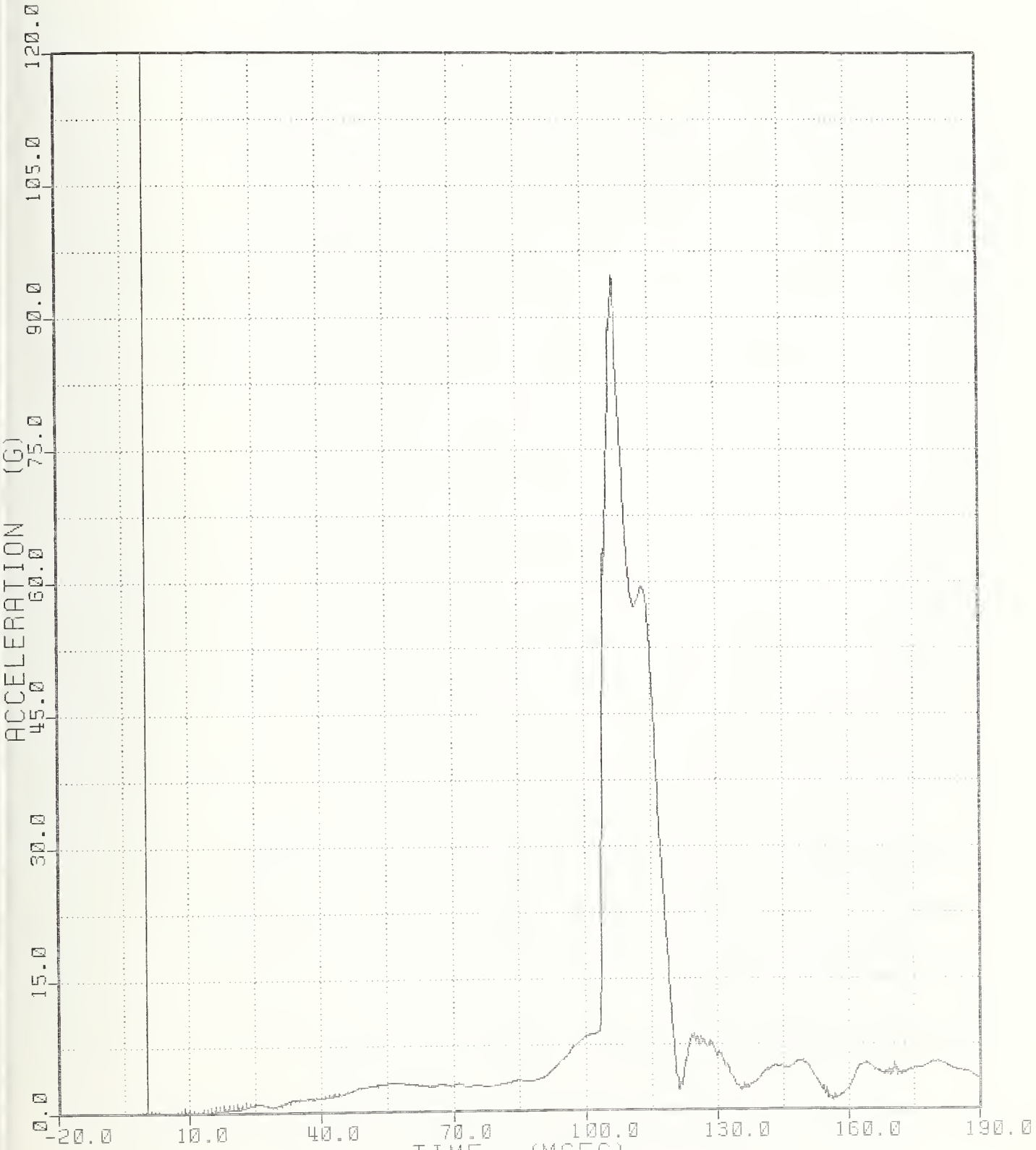
SRL66-9 LATERAL HEAD ACCELERATION

SRL669 VRTC SRL66-9 84045 10-JUL-84 11:41:15
HEDZG1 FILTER = ALPF 1650/ 5214/ -40 15.1 MPH
MIN, MAX VALUES = -75.997 @ 106.8750 17.362 @ 114.0000



SRL66-9 VERTICAL HEAD ACCELERATION

SRL669 VRTC SRL66-9 84045 10-JUL-84 11:41:15
HEDRG1 FILTER = ALPF 1650/ 5214/ -40 15.1 MPH
MIN, MAX VALUES = 0.014 @ -19.7500 94.859 @ 106.8750



SRL66-9 RESULTANT HEAD ACCELERATION

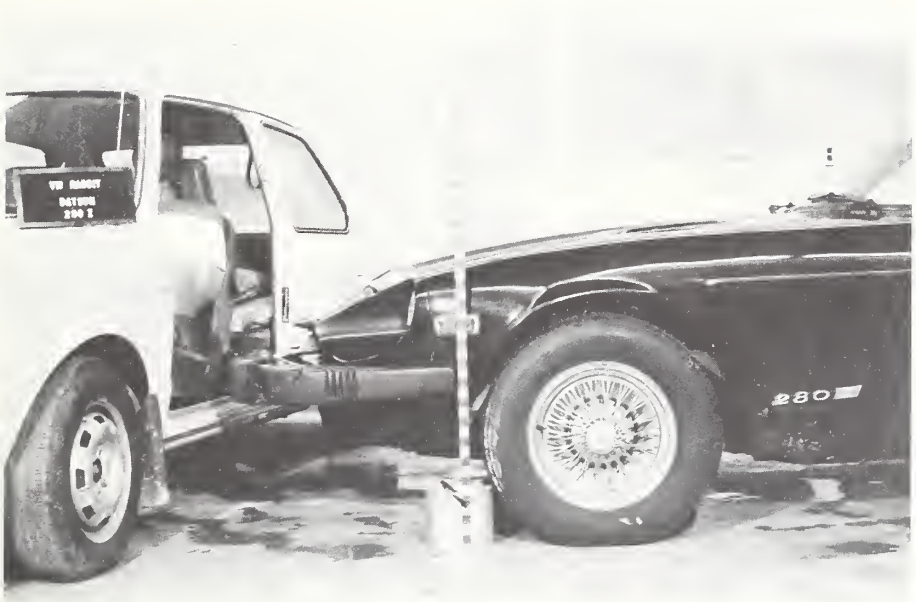
APPENDIX F

Preliminary Survey of Front End Profiles

This section contains photographs of the twenty vehicles that were selected for this survey. The selection was made on the basis of availability at the VRTC. These pictures show the front end profile and its relative positioning to a seated dummy for each vehicle. The dummy was normally seated in a VW Rabbit. The white wrap around the dummy thoracic area indicates the location of the rib cage.

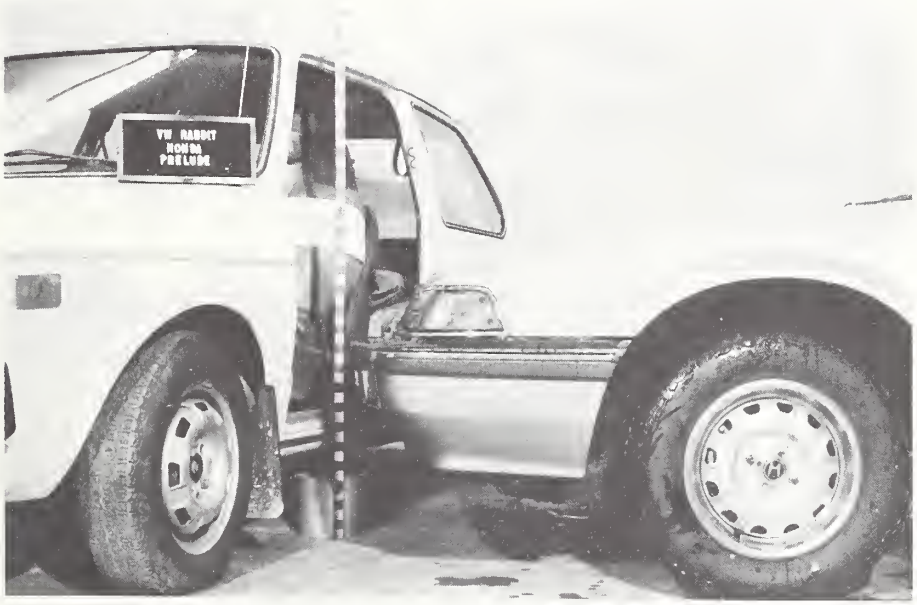
The twenty vehicles were as follows:

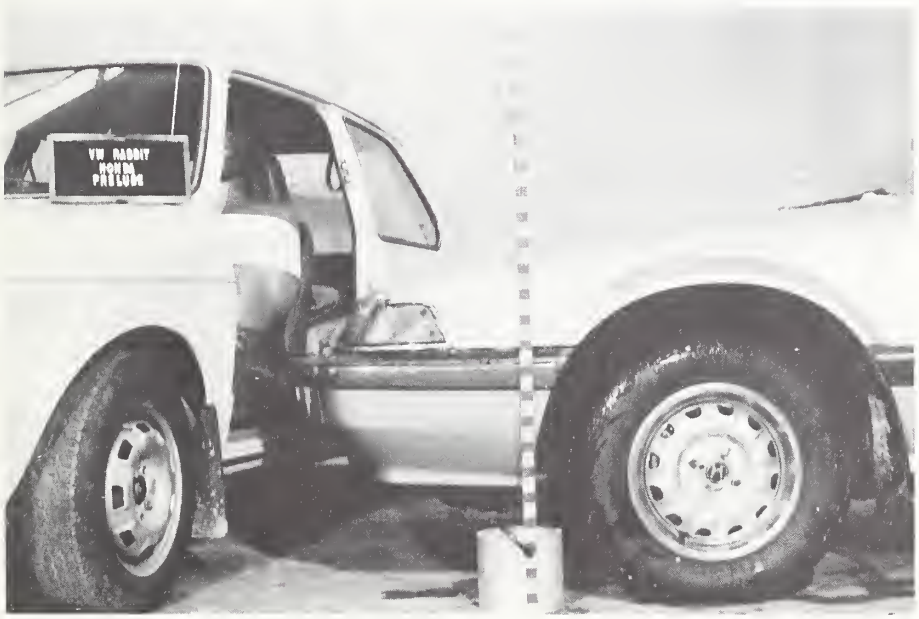
Datsun 280 Z	Isuzu Impulse
Honda Prelude	Toyota Camry
Plymouth Turismo	Mitsubishi Starion
Nissan Sentra	Toyota Celica
Chevrolet Cavalier	Plymouth Horizon
Mercury Lynx	Dodge 600
Chevrolet Chevette	Buick Skylark
Ford Thunderbird	Datsun 810 Wagon
AMC Spirit	Ford LTD Wagon
Volvo GL	Ford Bronco



Datsun 280 Z

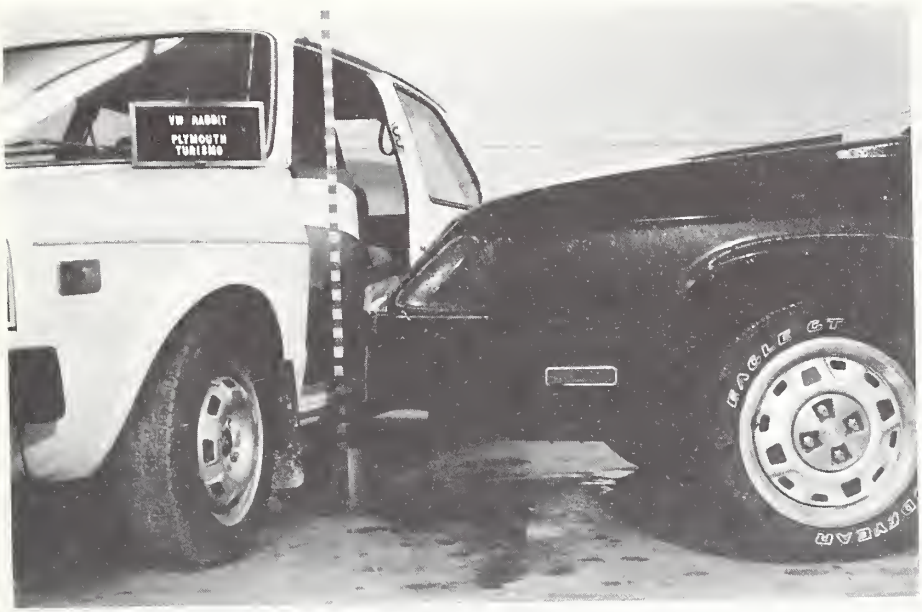
Isuzu Impulse

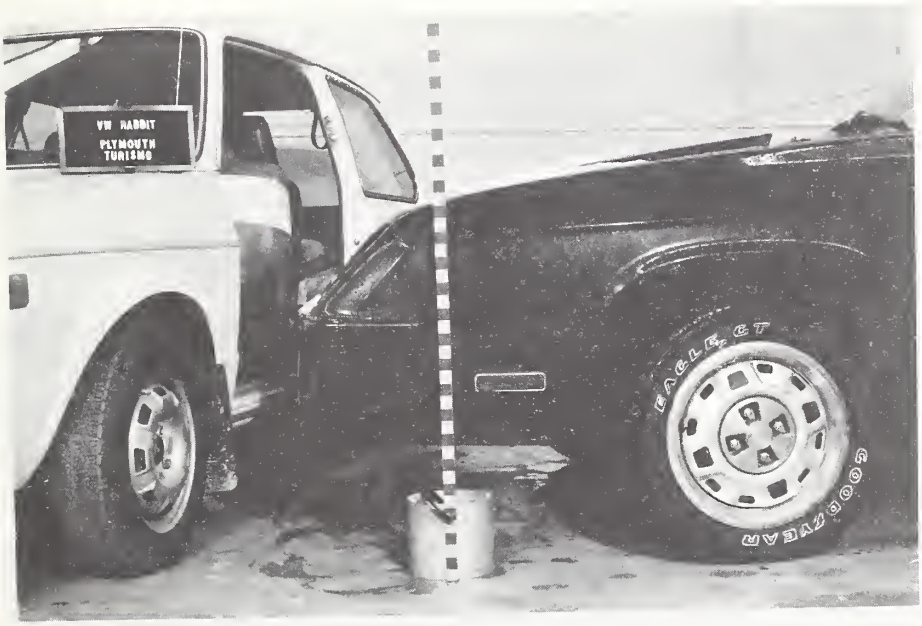




Honda Prelude

Toyota Camry





Plymouth Turismo

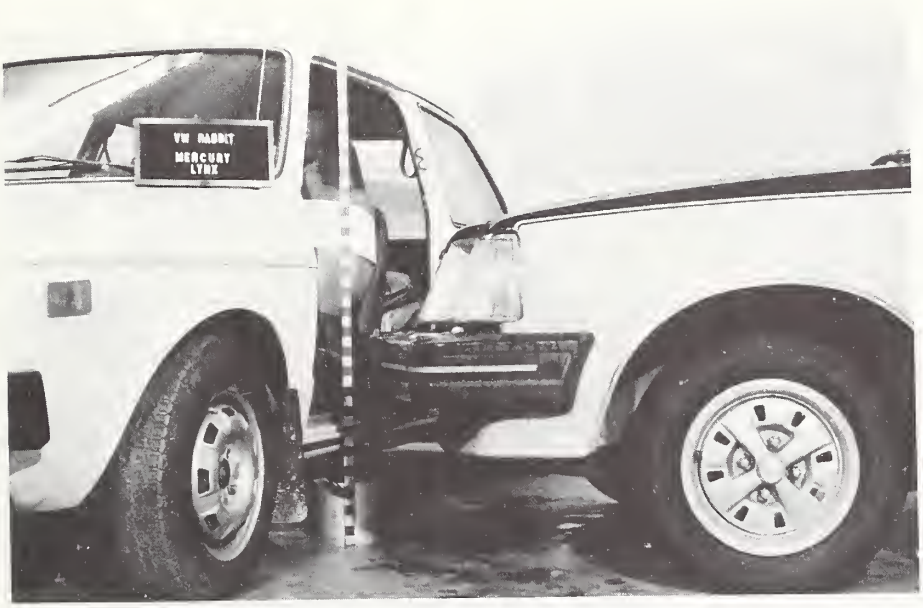
Mitsubishi Starion

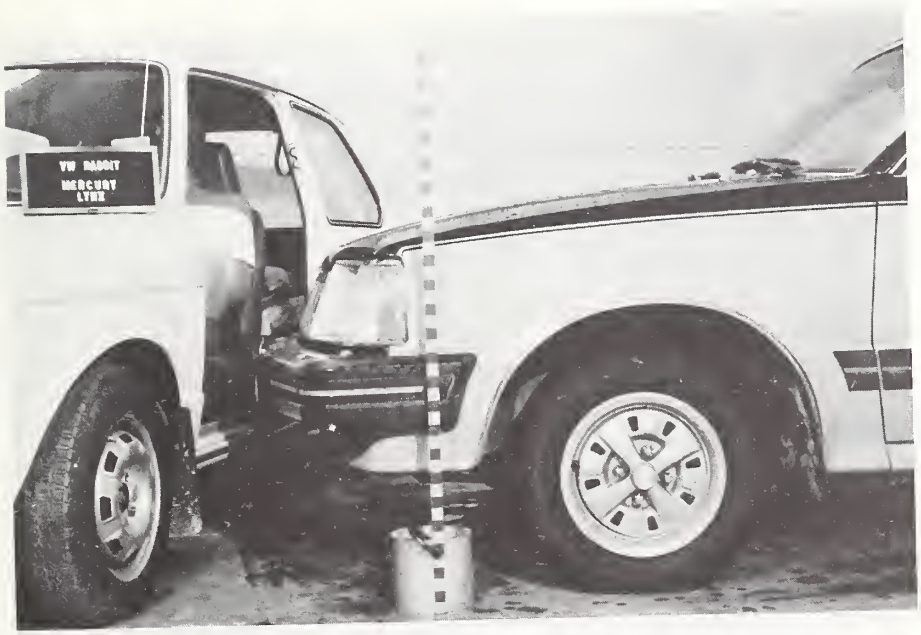
Nissan Sentra

Toyota Celica

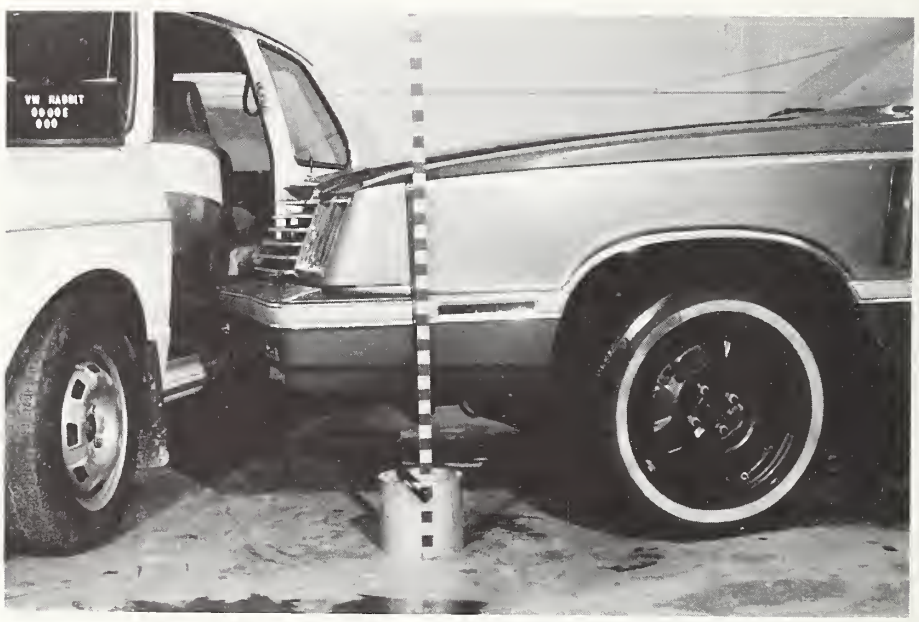
Chevrolet Cavalier

Plymouth Horizon

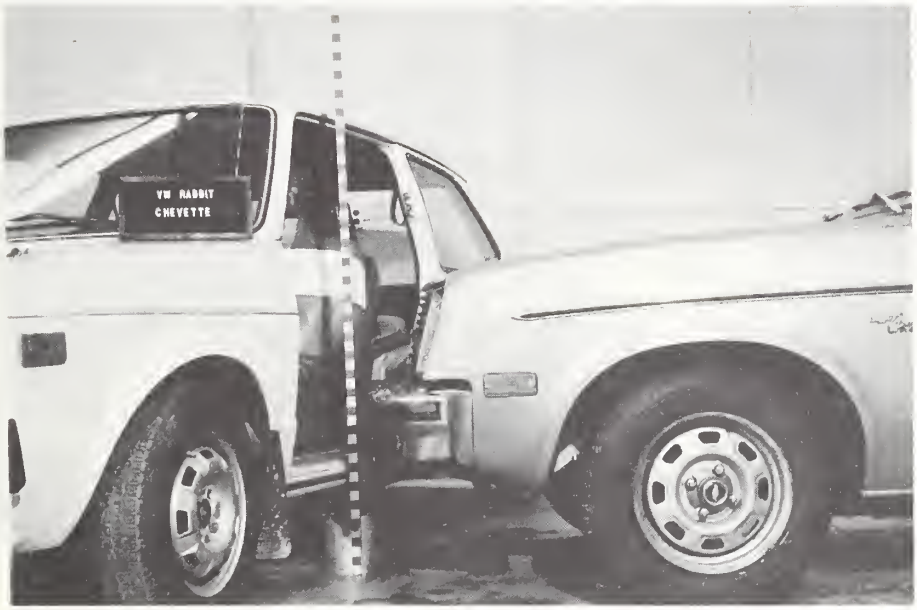




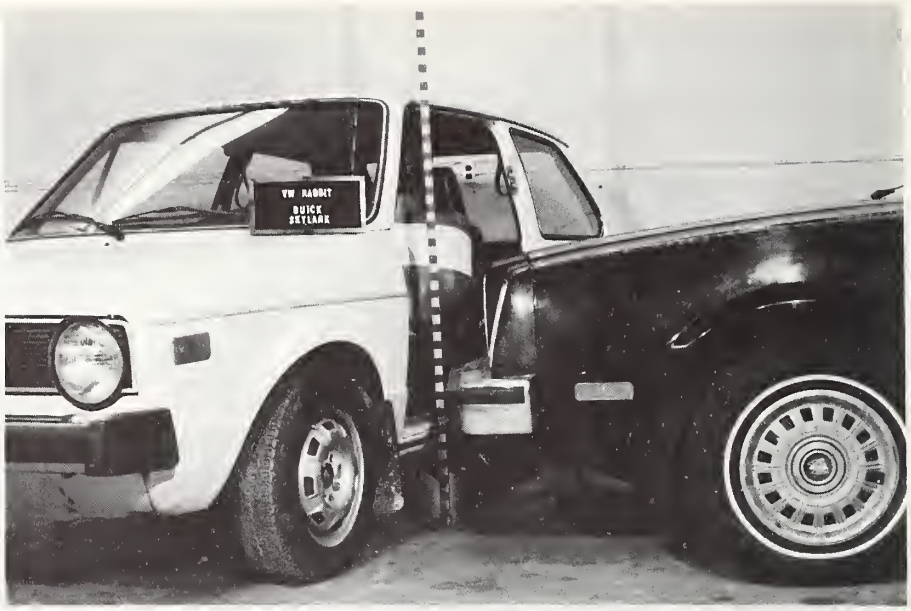
Mercury Lynx



Dodge 600



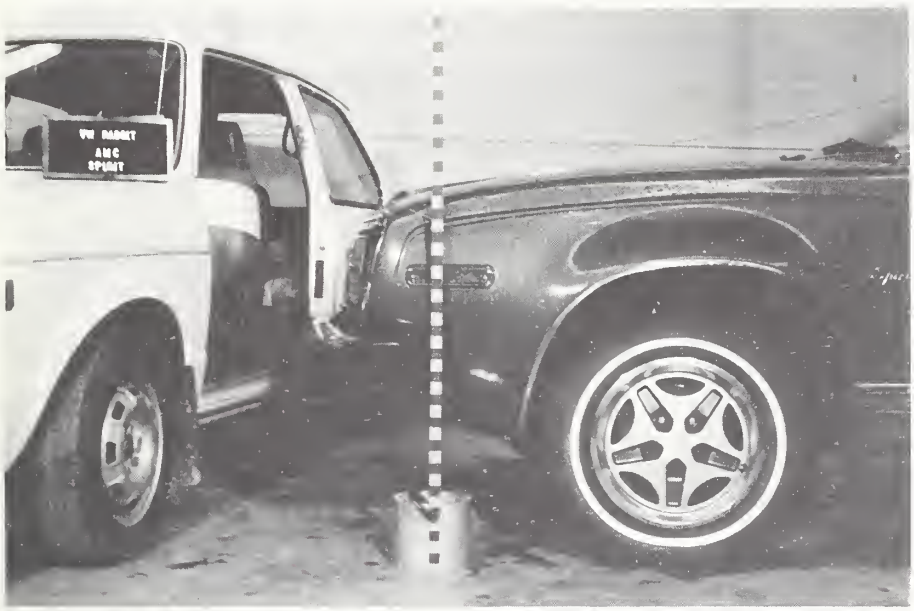
Chevrolet Chevette



Buick Skylark

Ford Thunderbird

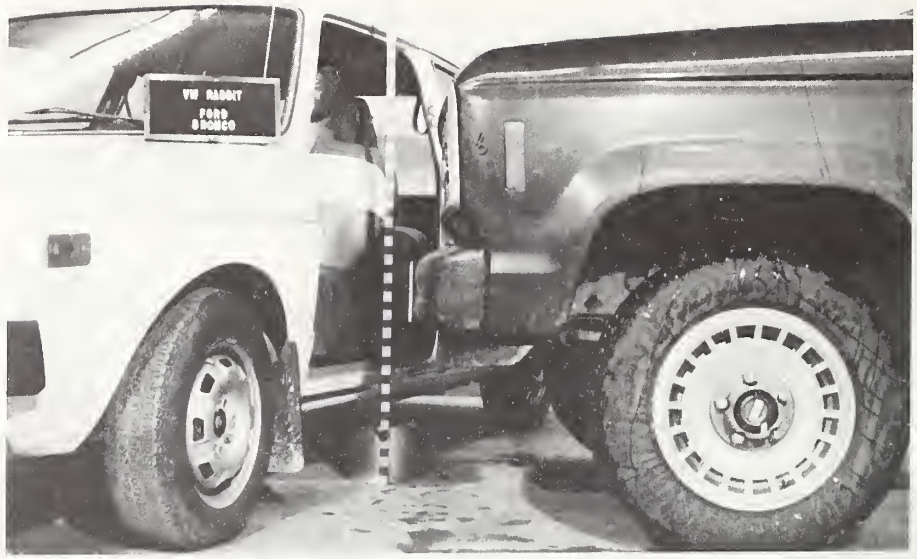
Datsun 810 Wagon



AMC Spirit

Ford LTD Wagon

Volvo GL



Ford Bronco

TL 242 .W54 19

Willke, Donald

Side interior
measurement

Form DOT F 1720.2 (8

FORMERLY FORM DOT F 170

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